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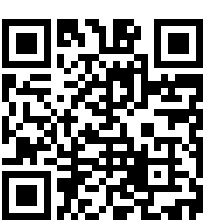

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TERRESTRIAL MAGNETISM
AND
ATMOSPHERIC ELECTRICITY

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TERRESTRIAL MAGNETISM

AND

ATMOSPHERIC ELECTRICITY

AN INTERNATIONAL QUARTERLY JOURNAL

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Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME VIII MARCH, 1903 NUMBER 1

DIE BEABSICHTIGTE NORWEGISCHE EXPEDITION NACH DEM MAGNETISCHEN NORDPOL.[1]

VON ROALD AMUNDSEN, Leiter der Expedition.

Wenn ich dem für mich so ehrenvollen Ersuchen der Gesellschaft für Erdkunde, über meine beabsichtigte Reise einige Angaben zu machen, gern und mit bestem Danke Folge leiste, so geschieht dies in dem Bewusstsein, dass es für mich nur von dem grössten Nutzen sein kann, vor so hervorragenden Fachleuten meine Pläne zu entwickeln. Ich möchte deshalb die Herren bitten, mir jedes Bedenken gegen das Eine oder das Andere in meinem Vorhaben rückhaltslos zu äussern.

In schwierigen Verhältnissen kann oft ein guter Rath von weittragender Bedeutung sein. Meine Theilnahme an der antarktischen Expedition der Belgica gab mir die erste Veranlassung zu dem Projekt.

Es war ja auf jener Expedition beabsichtigt, zum magnetischen Südpol zu gelangen und die Ausrüstung an magnetischen Instrumenten war dementsprechend eine recht gute. Da jedoch die Expedition zu spät von Süd-Amerika aufbrach, war es nicht mehr möglich über Australien bis in die Gegend des magnetischen Südpols vorzudringen. Wir fuhren von Süd-Amerika direkt nach

[1]Einen Vortrag gehalten in der Gesellschaft für Erdkunde, Berlin, December 1902.

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Süden, sassen dann bald im Eise fest und hatten in dieser Situation Zeit und Musse genug, um über andere Unternehmungen nachzudenken. Da ich mich an den magnetischen Messungen auf der Belgica betheiligte, wollte ich die gewonnenen Erfahrungen zu einer Erforschung des magnetischen Nordpols weiter verwerthen. Ich habe mich aber bei meinem Vorhaben nur von dem einen Gedanken leiten lassen, womöglich der Wissenschaft einigen Nutzen zu leisten, und aus diesem Grunde einen solchen Reiseweg in Aussicht genommen, dass ein Erfolg möglichst gesichert wird.

Es liegt mir deshalb fern, unter grossen Schwierigkeiten und Gefahren neue Länder zu entdecken oder vielleicht gar zum astronomischen Nordpol zu gelangen. Wenn ich überhaupt den Wunsch hätte, diesen Pol zu finden, so hätte ich ihn sicher nur deshalb, um damit allen—ich möchte sagen, sportmässigen—Expeditionen dorthin ein Ende zu machen.

Nach der Rückkehr der Belgica wandte ich mich im September 1900 an den Direktor der deutschen Seewarte, Herrn Geheimrath von Neumayer, und legte ihm meinen Plan vor, in der Gegend des magnetischen Nordpols magnetische, meteorologische und geologische Beobachtungen auszuführen. Herr Geheimrath stimmte meinem Plan vollständig zu und gab mir während eines Aufenthalts von zwei Monaten an der Seewarte in seiner allbekannten Liebenswürdigkeit die beste Unterweisung, welche ich haben konnte. Ich finde nicht die Worte, um meine warmen Gefühle grösster Dankbarkeit für Herrn Geheimrath von Neumayer zum rechten Ausdruck zu bringen. Auf seinen Rath bestellte ich ein magnetisches Reiseinstrument nach seiner Construktion beim Mechaniker Saemann in Hamburg und ein Inclinatorium bei Dover in Kent.

In Norwegen und Schweden äusserten sich die Herren Prof. Nansen und Prof. Geelmuyden ebenfalls sehr günstig über mein Vorhaben.

Im Jahre 1901 kaufte ich dann ein kleines Schiff — Gjöa genannt—für arktische Schifffahrt speciell gebaut.

Um die Eigenschaften des Schiffes gründlich kennen zu lernen, und eventuell noch geeignete Abänderungen zu treffen, unternahm ich mit der Gjöa eine sechsmonatliche Reise nach Novaja Zemblja, Spitzbergen und Grönland. Gleichzeitig machte ich oceanographische Untersuchungen in dem Grönländischen Polarstrom als Abschluss der gleichartigen Beobachtungen von Herrn Prof. Nansen auf dem Fram 1903–1906.

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Im Juni und Juli 1902 war ich in Wilhelmshaven, um die Constanten meiner Instrumente zu bestimmen.

Den Herren Geheimrath Börgen und Prof. Stück bin ich ebenfalls für ihre grosse Unterstützung, welche sie mir andauernd zu Theil werden liessen, zu höchstem Danke verpflichtet.

Zur weiteren Einübung führte ich dann mit meinen Instrumenten in Gemeinschaft mit Herrn Axel Steen an verschiedenen Orten in Norwegen magnetische Messungen aus. An Herrn Prof. Schmidt hatte ich mich bereits früher um Rath gewandt, damit ich in kompetentester Weise darüber unterrichtet war, welche Messungen ich auszuführen hatte, um ihnen vom theoretischen Standpunkt aus den grössten Werth zu verleihen. Da ich beabsichtige, auch magnetische Registrirungen mit Instrumenten nach Eschenhagen durchzuführen, suchte ich Herrn Prof. Schmidt am magnetischen Observatorium zu Potsdam auf, um die Instrumente zu bestellen und gleichzeitig die Constanten der magnetischen Instrumente, welche bei der letzten Fram Expedition benutzt wurden und welche ich ebenfalls zu verwerthen gedenke, neu zu prüfen.

Auf den Rath des Herrn Prof. Schmidt gedenke ich die Basis-Station—von der aus dann kleinere Expeditionen unternommen werden sollen—dem magnetischen Pol nicht allzu nahe zu errichten, damit daselbst alle magnetischen Elemente noch mit *grösserer* Sicherheit bestimmt werden können und damit besonders die Veränderlichkeit der Declination, genaue Messungen nicht gar zu sehr erschwert.

Ich werde daselbst die Declination, Horizontal-Intensität und Vertical-Intensität ganz in der Weise registriren, wie sie von Herrn Prof. Eschenhagen im "Terrestrial Magnetism" beschrieben ist. Die drei Instrumente stehen hintereinander, erhalten von einer Lampe Licht und registriren dann ihren Stand zugleich auf dem photographischen Papier einer Walze. Nur wird es sich für meine Zwecke empfehlen, die Entfernungen der Instrumente etwas anders zu wählen.

Die absoluten magnetischen Messungen werden während der Winterzeit mit zwei Reiseinstrumenten, einem Fox Apparat und einem Erdinductor nach Wild-Eschenhagen ausgeführt werden. In den kleineren Expeditionen werde ich nur das eine Reiseinstrument und vielleicht auch den Fox Apparat mitnehmen.

Wie ich dies bereits vor einem Jahre in einem Vortrage in Christiania hervorgehoben habe, werde ich mich im wesentlichen

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darauf beschränken müssen, den magnetischen Pol in einem beträchtlichen Abstand von mindestens 200 km. zu umkreisen, da die Beobachtungen in nächster Nähe des Pols zu unsicher sein werden und zu grossen Täuschungen Veranlassung geben könnten. Die Messungen würden eigentlich nur als Local-Untersuchungen zu bezeichnen sein, welche um so weniger allgemeinen Werth haben, als daselbst infolge der grösseren Total-Intensität die Local-Störungen voraussichtlich recht erheblich sein werden und infolge des geringen absoluten Werthes der Horizontal-Intensität viel mehr zur Geltung kommen als anderswo. Genaue Messungen würden dort auch mit mancherlei Schwierigkeiten mehr instrumenteller Natur verknüpft sein; das Mess-Instrument müsste im grossen und ganzen mehr als Local-Variometer ausgestattet sein.

Aus instrumentellen Gründen werde ich zur grösseren Sicherheit eine Anzahl Magnete von verschiedenstem Moment mitnehmen. Dieselben sollen so in eisernen Behältern verpackt sein, dass sie ihre Momente erfahrungsgemäss sehr constant erhalten. Dann bin ich in der Lage, die Horizontal-Intensität entweder durch Ablenkungen oder durch Schwingungen allein zu messen.

Messungen ersterer Art werden besonders während der Schlitten-Expeditionen vorzuziehen sein, während sich der Anschluss meiner Basis-Station an Potsdam hinsichtlich der Horizontal-Intensität vielleicht am besten durch Schwingungs-Beobachtungen ausführen lässt. Ich beabsichtige aber etappenweise von hier aus bis zu meiner Station Messungen auszuführen, um die Ablenkungs-Constanten von Magneten, welche sich hier wegen der kleinen Ablenkungs-Winkel nicht mit genügender Sicherheit bestimmen lassen, unterwegs zu ermitteln.

Die Gjöa, das Expeditionsschiff, ist, wie gesagt, nur klein, aber gerade dadurch wie auch durch ihre starke Bauart besonders für die Eisregion geeignet; ich hoffe mit ihr leichter als mit einem grösseren Schiffe durch die schmalen Fahrstrassen jener Gewässer zu kommen, welche ich durchforschen will. Das Schiff ist 70 Fuss lang, 20 Fuss breit und hält 48 Registertons, ich habe es aber noch durch schwere Holz- und Eisenbalken verstärken lassen. Auch ist es jetzt mit einem kleinen Petroleummotor versehen und läuft mit diesem etwa 4 Knoten in der Stunde. 30,000 Liter Petroleum in eisernen Behältern sollen zur Heizung, zum Kochen und als Triebkraft für den Motor dienen. Das Petroleum wird aber grossenteils durch schottische Walfishfänger bis in die Nähe der Gegend gebracht, wo ich voraussichtlich zunächst überwintern werde.

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Proviant nehme ich für 4–6 Jahre mit, sowie eine möglichst gute Ausrüstung für eine Polar-Expedition.

Die Besatzung wird aus acht Mann bestehen, von denen zwei—ein Assistent und ich—im wesentlichen die magnetischen Arbeiten übernehmen, während ein dänischer Marine-Officier hauptsächlich geologische Studien machen wird.

Von Christiania werde ich voraussichtlich am 15. April 1903 aufbrechen. In Godhavn, auf der Insel Disco, auf der Westseite von Grönland, will ich mich mit Polarhunden versehen und magnetische Messungen ausführen. Solche Messungen sollen weiterhin an allen Orten, wo es möglich ist, angestellt werden, damit ich daraus auf die gegenwärtige Lage des magnetischen Nordpols Schlüsse ziehen kann. Wie mir mehrere Walfischfahrer mittheilten, fangen bereits in der Lancaster Strasse die besten Compasse von William Thomson an, ganz unzuverlässig zu werden.

Nach den bisherigen Ueberlegungen werde ich die Basis-Station am Leopold Hafen auf Nord Somerset einrichten. Da jedoch für die Wahl dieser Station mancherlei mitspricht, worüber ich vorläufig selber nichts Näheres weiss, kann ich natürlich keine ganz bestimmten Angaben über die Lage dieser Station machen. Auf jeden Fall möchte ich versuchen, im Sommer 1904 durch schottische Walfischfahrer, welche diesen Hafen gewöhnlich aufsuchen, Nachricht von mir nach Europa gelangen zu lassen. Auf der Station wird im Spätsommer und während des Winters mit der Einrichtung, sowie mit den absoluten Messungen und anderen Beobachtungen genügend zu thun sein. Der Raum für das Registrir-Observatorium wird im wesentlichen aus leeren Proviantkisten hergestellt werden; mit den Wohnräumen soll dieses Observatorium durch einen allseitig gedeckten Gang verbunden sein, um auch bei starken Schneeverwehungen noch sicher und bequem dorthin zu gelangen. Das absolute Observatorium wird im Winter aus einer Schneehütte bestehen. Im Sommer werde ich dazu ein festes Zelt benutzen, dessen Decke aus durchsichtiger weisser Seide besteht, wodurch ich genügendes Oberlicht für die Messungen erhalte. Während des Sommers gedenke ich dann eine Anzahl von Schlittenexpeditionen auszuführen, um einen möglichst grossen Theil des Gebiets rings um den magnetischen Pol zu vermessen. Ich will in diesem Sommer auch versuchen, mit dem Schiff einen Weg nach King William Insel zu finden, um im zweiten Sommer das Observatorium dorthin zu verlegen und nun von dort aus neue kleinere Expeditionen auszuführen. Im dritten Sommer

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also 1906 will ich dann versuchen, in der Gegend der Herschel Insel meine Basis-Station zu errichten. Dort hoffe ich wohl Gelegenheit zu haben, mit McPherson—dem nördlichsten Fort der britischen Handels-Compagnie—in Verbindung zu treten. Hier sollen dann die Messungen ganz ebenso wie in den Jahren vorher fortgesetzt werden. Nach Ablauf der Zeit, welche ich mir gesetzt habe, werde ich dann die Rückreise um Alaska herum antreten und womöglich in Sitka Anschlussmessungen am magnetischen Observatorium der Vereinigten Staaten "Coast and Geodetic Survey" machen.

Ich schliesse meine Mittheilung, indem ich der Gesellschaft nochmals meinen Dank für die freundliche Einladung ausspreche.

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MEAN VALUES OF THE MAGNETIC ELEMENTS AT OBSERVATORIES.

COMPILED BY D. L. HAZARD.[1]

Place	Latitude	Longitude	Year	Declination	Inclination	Intensity (C. G. S. Units)	
						Hor'l	Vert'l
	° ′	° ′		° ′	° ′		
Pawlowsk	59 41 N	30 29 E	1898	0 30 ·3 E	70 39 ·7 N	·16522	·47077
			1899	0 34 ·1 E	70 38 ·8 N	·16536	·47078
Sitka[2]	57 03 N	135 20 W	1902	29 50 ·0 E	74 48 ·3 N	·15410	——
Katharinenburg	56 49 N	60 38 E	1898	9 55 ·6 E	70 40 ·2 N	·17802	·50752
			1899	9 59 ·6 E	70 39 ·7 N	·17795	·50706
Kasan	55 47 N	49 08 E	1894	7 39 ·7 E	68 37 ·5 N	·18572	·47451
			1895	7 43 ·8 E	68 35 ·5 N	·18580	·47390
			1896	7 47 ·1 E	68 33 ·7 N	·18605	·47381
			1897	7 54 ·8 E	68 34 ·8 N	·18616	·47454
Copenhagen	55 41 N	12 34 E	1899	10 15 ·8 W	68 40 ·0 N	·17490	·4478
Stonyhurst	53 51 N	2 28 W	1899	18 17 ·7 W	68 51 ·8 N	·17273	·44677
			1900	18 10 ·9 W	68 50 ·3 N	·17312	·44720
			1901	18 09 ·7 W	68 45 ·7 N	·17348	·44638
Hamburg	53 34 N	10 03 E	1896	11 36 ·7 W	67 38 ·8 N	·18061	·43921
Wilhelmshaven	53 32 N	8 09 E	1899	12 31 ·9 W	67 45 ·0 N	·18072	·44173
Potsdam	52 23 N	13 04 E	1899	10 00 ·7 W	66 33 ·3 N	·18818	·43392
			1900	9 56 ·3 W	66 33 ·7 N	·18844	·43466
Irkutsk	52 16 N	104 16 E	1898	2 02 ·6 E	70 13 ·2 N	·20137	·55991
			1899	2 01 ·5 E	70 13 ·7 N	·20133	·56009
de Bilt (Utrecht)	52 05 N	5 11 E	1898	13 59 ·1 W	——	·18487	——
			1899	13 54 ·7 W	——	·18502	——
Cahirciveen[3]	51 56 N	10 15 W	1899	21 35 ·0 W	68 33 ·0 N	·17739	·45164
			1900	21 30 ·0 W	68 29 ·6 N	·17765	·45082
			1901	21 27 ·7 W	68 26 ·3 N	·17801	·45048
Kew	51 28 N	0 19 W	1900	16 52 ·7 W	67 11 ·8 N	·18428	·43831
Greenwich	51 28 N	0 00	1899	16 34 ·2 W	67 10 ·2 N	·18419	·43754
			1900	16 29 ·0 W	67 08 ·5 N	·18450	·43764
Uccle (Brussels)	50 48 N	4 21 E	1899	14 18 ·3 W	66 13 ·2 N	·18938	·42978
			1900	14 13 ·6 W	66 09 ·8 N	·18952	·42896
Falmouth	50 09 N	5 05 W	1899	18 32 ·7 W	66 48 ·7 N	·18663	·43569
			1900	18 29 ·1 W	66 45 ·2 N	·18689	·43507
Prague	50 05 N	14 25 E	1899	9 11 ·9 W	——	·19926	——
			1900	9 07 ·0 W	——	·19947	——
			1901	9 01 ·7 W	——	·19965	——
St. Helier (Jersey)	49 12 N	2 05 W	1900	16 59 ·7 W	65 45 ·5 N	——	——
			1901	16 56 ·5 W	65 42 ·7 N	——	——
Parc St. Maur	48 49 N	2 29 E	1898	14 53 ·8 W	64 58 ·3 N	·19676	·42140
			1899	14 49 ·5 W	64 55 ·7 N	·19704	·42119
Vienna	48 15 N	16 21 E	1898	8 24 ·1 W	——	·20797	——
O'Gyalla (Pesth)	47 53 N	18 12 E	1900	7 28 ·8 W	——	·21153	——
Odessa[4]	46 26 N	30 46 E	1898	4 41 ·5 W	62 30 ·5 N	·22033	·42341
			1899	4 36 ·7 W	62 18 ·9 N	·21869	·41660
			1900	4 29 ·9 W	62 18 ·0 N	·21876	·41659

[1] Use was made in this compilation of Dr. Chree's, table in *Proc. Roy Soc.* for 1901.

[2] Absolute observations January to June; preliminary results.

[3] Absolute observations only.

[4] There was evidently a change in the dip instrument between 1898 and 1899.

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Place	Latitude	Longitude	Year	Declination	Inclination	Intensity (C. G. S. Units) Hor'l	Vert'l
Pola	44 52 N	15 51 E	1899	9 25 ·7 W	60 21 ·6 N	·22135	·38900
			1900	9 25 ·3 W	60 15 ·9 N	·22202	·38871
			1901	9 20 ·1 W	60 13 ·2 N	·22230	·38848
Nice	43 43 N	7 16 E	1899	12 04 ·0 W	60 11 ·7 N	·22390	·39087
Toronto	43 40 N	79 30 W	1897	4 53 ·0 W	———	·16650	—
Perpignan [1]	42 42 N	2 53 E	1897	13 51 ·3 W	60 03 ·5 N	·22440	·38959
			1898	13 47 ·0 W	60 01 ·7 N	·22386	·38818
			1899	13 42 ·5 W	60 00 ·0 N	·22418	·38829
Tiflis	41 43 N	44 48 E	1897	1 59 ·0 E	55 48 ·3 N	·25664	·37770
			1898	2 05 ·5 E	55 50 ·6 N	·25635	·37784
Capodimonte (Naples)	40 52 N	14 15 E	1898	9 22 ·6 W	———	—	—
			1899	9 15 ·8 W	———	—	—
			1900	9 10 ·2 W	———	—	—
Madrid	40 25 N	3 40 W	1898	15 51 ·3 W	———	—	—
			1899	15 48 ·4 W	———	—	—
Coimbra	40 12 N	8 25 W	1899	17 24 ·2 W	59 28 ·9 N	·22724	·38549
Baldwin [2]	38 47 N	95 10 W	1901	8 23 ·0 W	68 34 ·7 N	·21955	—
Cheltenham [3]	38 44 N	76 50 W	1902	5 06 .0 W	70 22 ·6 N	·20194	—
Lisbon	38 43 N	9 09 W	1900	17 18 ·0 W	57 54 ·8 W	·23516	·37484
Tokio	35 41 N	139 45 E	1897	4 29 ·9 W	49 02 ·8 W	·29816	·34356
Zi-ka-wei	31 12 N	121 26 E	1897	2 18 ·5 W	45 53 ·0 N	·32799	·33827
			1898	2 19 0 W	45 48 ·7 N	·32778	·33720
Havana	23 08 N	82 25 W	1898	3 10 ·8 E	52 30 ·7 N	·31166	·40034
Hong Kong	22 18 N	114 10 E	1899	0 21 ·1 E	31 29 ·4 N	·36676	·22463
Honolulu [3]	21 19 N	158 04 W	1902	9 17 ·4 E	40 14 ·7 N	·29245	—
Tacubaya	19 24 N	99 12 E	1895	7 45 ·6 E	44 22 ·2 N	·33428	·32764
Colaba (Bombay)	18 54 N	72 49 E	1897	0 32 ·5 E	20 59 ·1 N	·37449	·14304
			1898	0 29 ·7 E	21 05 ·8 N	·37435	·14448
			1899	0 26 ·5 E	21 13 ·9 N	·37437	·14540
Manila	14 35 N	120 58 E	1898	0 51 ·4 E	16 28 ·7 N	·37952	·11228
			1899	0 51 ·9 E	16 19 ·9 N	·37981	·11130
			1900	0 52 ·1 E	16 15 ·9 N	·38029	·11095
Batavia	6 11 S	106 49 E	1898	1 14 ·9 E	29 47 ·4 S	·36752	·21040
Dar-es-salem [4]	6 49 S	39 18 E	1896	8 41 ·6 W	36 50 ·8 S	·29004	·21735
			1897	8 29 ·9 W	36 53 ·3 S	·29009	·21771
			1898	8 18 ·1 W	36 56 ·8 S	·28966	·21785
Mauritius	20 06 S	57 33 E	1898	9 39 ·2 W	54 22 ·4 S	·23873	·33514
			1899	9 32 ·9 W	54 16 ·8 S	·23854	·33171
Rio de Janeiro [5]	22 55 S	43 11 W	1899	7 47 ·4 W	13 15 ·3 S	·2503	·0599
			1900	7 55 ·7 W	13 17 ·1 S	·2504	·0592
			1901	8 10 ·0 W	13 22 ·8 S	·2500	·0595
Melbourne	37 50 S	144 58 E	1898	8 20 ·1 E	67 22 ·4 S	·23364	·56050

[1] Intensity results at Perpignan prior to 1898 require the following corrections in order to reduce to the same standard as later results: Horizontal intensity,—.00088; vertical intensity,—.00153.

[2] Preliminary results from absolute observations.

[3] Absolute observations January to June; preliminary results.

[4] Data for 1896 and 1897 are from absolute observations only. For 1898 use was made of available magnetograph records.

[5] Absolute observations only.

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THE CHRISTCHURCH MAGNETIC OBSERVATORY, NEW ZEALAND.

By C. Coleridge Farr, D. Sc.

The Observatory is situated in the Christchurch Botanical Gardens, in latitude 43° 31′ 50″ S.; longitude 172° 37′ 18″ E. The time employed in New Zealand is that of longitude 172° 30′ 00″ E., or 11^h 30^m E., and when Greenwich time is not stated as being adopted, it is this local standard time which is used at the observatory.

FIGURE 1. CHRISTCHURCH MAGNETIC OBSERVATORY; ABSOLUTE HOUSE.

The observatory consists of three buildings, situated sufficiently far from one another for the operations carried on in one to be without appreciable effect in the others. The "absolute house" and "variation house" are both constructed of material which has been tested and found free from magnetic effect. The absolute house is built of wood fastened with copper nails and brass screws; the roofing is of slate.

The superstructure of the variation house is similar in construction, whilst underneath the visible portion is a cellar in which the instruments (magnetograph, of the Kew pattern) are placed. The cellar was designed to maintain as uniform a temperature as possible, and the scheme has been very successful. The walls, built of concrete tested, are double, the outer one being one foot in thickness, and the inner nine inches thick, whilst between the two there is an air space all around three inches thick. The diurnal change of temperature is usually scarcely visible, though under exceptional circumstances the temperature may rise or fall a degree (Fahr.) in the twenty-four hours. The annual range of temperature is about 14° Fahr. The magnetograph work has been in progress since November, 1901.

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Place	Latitude	Longitude	Year	Declination	Inclination	Intensity (C. G. S. Units) Hor'l	Intensity (C. G. S. Units) Vert'l
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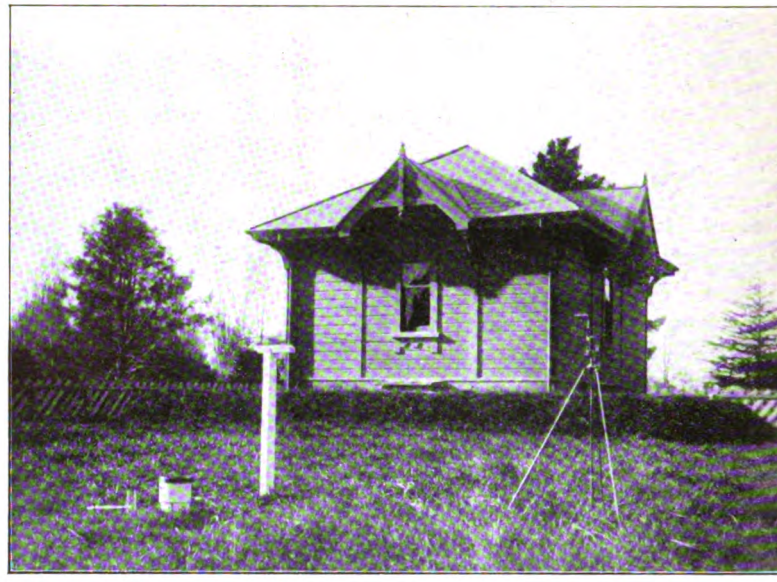

FIGURE 2. CHRISTCHURCH MAGNETIC OBSERVATORY; VARIATION HOUSE.
[Magnetographs in cellar below.]

Besides the magnetic work, a Milne seismograph is installed and observations of atmospheric potential and the dissipation of electric changes are also made. There is also a set of meteorological instruments. The observatory is the base station of the British National Antarctic Expedition, and also of the Magnetic Survey of the Colony of New Zealand.

FIGURE 3. CHRISTCHURCH MAGNETIC OBSERVATORY; OFFICES AND SEISMOGRAPH CELLAR.

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THE MAGNETIC OBSERVATORIES OF THE UNITED STATES COAST AND GEODETIC SURVEY IN OPERATION ON JULY 1, 1902.

By L. A. Bauer and J. A. Fleming.

I. SELECTION OF SITES OF THE MAGNETIC OBSERVATORIES.

[Abstract].[1]

The United States Coast and Geodetic Survey has in operation, in conformity with the plan of the magnetic survey of the United States and countries under its jurisdiction, outlined in Appendix 10, Report of the Superintendent of the Coast and Geodetic Survey for 1899,[2] four magnetic observatories at which the manifold variations of the Earth's magnetism are being continuously recorded by photographic means. These continuous records, besides serving other useful purposes, are utilized in referring the values of the magnetic elements, obtained at various stations and at various times by the field parties engaged in the magnetic survey, to a common time.

These four magnetic observatories, which constitute at present the primary magnetic base stations of the magnetic survey of the United States and countries under its jurisdiction, are as follows:

1. *The Cheltenham Magnetic Observatory*, situated at Cheltenham, Md., fourteen miles, or twenty-two and one-half kilometers, in an air line southeast from the United States Capitol at Washington City. This is the principal or standard magnetic observatory, where, in addition to the regular observatory work, all magnetic instruments are standardized;

2. *The Sitka Magnetic Observatory*, located at Sitka, Alaska, near the new Russian cemetery. The magnetic and meteorological observatory, which the Russians had in operation between 1842 and 1867, was situated on Japonski Island, in Sitka Harbor, about three-eighths of a mile, or three-fifths of a kilometer, west of the present site;

3. *The Honolulu Magnetic Observatory*, located on an immense coral plain twelve and one-half miles, or twenty kilometers, in an air line, west of the city of Honolulu, Hawaii;

4. *The Baldwin Magnetic Observatory*, situated at Baldwin, Kas., thirteen miles, or twenty-one kilometers, in an air line, south of Lawrence, Kansas. This observatory is a temporary one, and the magnetograph was mounted in an existing structure. The site for a more permanent observatory in the Western States has not yet been chosen.

In addition to the above, the Survey is contemplating, in the near future, the erection of a magnetic observatory in Porto Rico,[3] a region

[1] Abstracted from Appendix No. 5, Report of the Superintendent of the United States Coast and Geodetic Survey for 1902.

[2] Also to be found in this Journal, Vol. III, pp. 93-104.

[3] A set of self-registering instruments (declination and horizontal intensity) was mounted temporarily in Fort Isabel, Vieques Island, east of Porto Rico, and put in operation in February, 1903.

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recommended as a desirable one for a magnetic observatory by the International Magnetic Conference held at Bristol, England, in 1898, and one which the recent volcanic eruptions in Martinique and concomitant magnetic storms have made doubly interesting and important for magnetic investigation. As soon as the magnetic survey of the extreme Western States is undertaken, the establishment of a magnetic observatory in that region will be imperative.

The selection of a suitable site for a magnetic observatory to be continuously and uninterruptedly in operation for a period of fifteen years, at least, is a most difficult matter in view of the rapid spread and development of electric car lines and electric power and lighting establishments. Nearly every prominent magnetic observatory over the entire globe has suffered more or less in recent years from stray industrial electric currents.

The disastrous effects from uninsulated electric car systems were first experienced in the United States, in 1892, at the Coast and Geodetic Survey magnetic observatory situated at San Antonio, Tex. When the facts were made known to prominent magneticians, some of them would not admit that the disturbances were due to stray currents from the San Antonio electric car line. To-day there is no longer any question that effects from such sources may be obtained five miles distant from the car lines.

Having these experiences in mind, special care was taken in the selection of the sites for the new magnetic observatories of the Coast and Geodetic Survey. The idea was abandoned altogether that it would be possible to maintain an observatory for several years in any locality already well settled or possessing inducements for settlement in the near future.

The next point of prime consideration is the uniformity in the distribution of magnetism within the area to be occupied for the various kinds of work at a magnetic observatory, so as to avoid the necessity of a reduction of the magnetic elements to a normal station, and thereby to eliminate the necessity of controlling the constancy of the reduction—following a rule that pertains especially to magnetic work, viz., to avoid, *ab initio*, any cause for correction.

Further points to be considered apply to accessibility of the station, to freedom from other disturbing influences than those from electrical sources, to facilities obtainable in the locality for carrying out the observatory work, such as supplies and abundance of pure water for the photographic work, comfort and convenience of observers, mail and telegraphic communications, etc. If other than magnetic work is to be carried on, such as investigations in atmospheric and telluric electricity, seismology, and meteorology, full consideration must likewise be given to the demands of these special branches.

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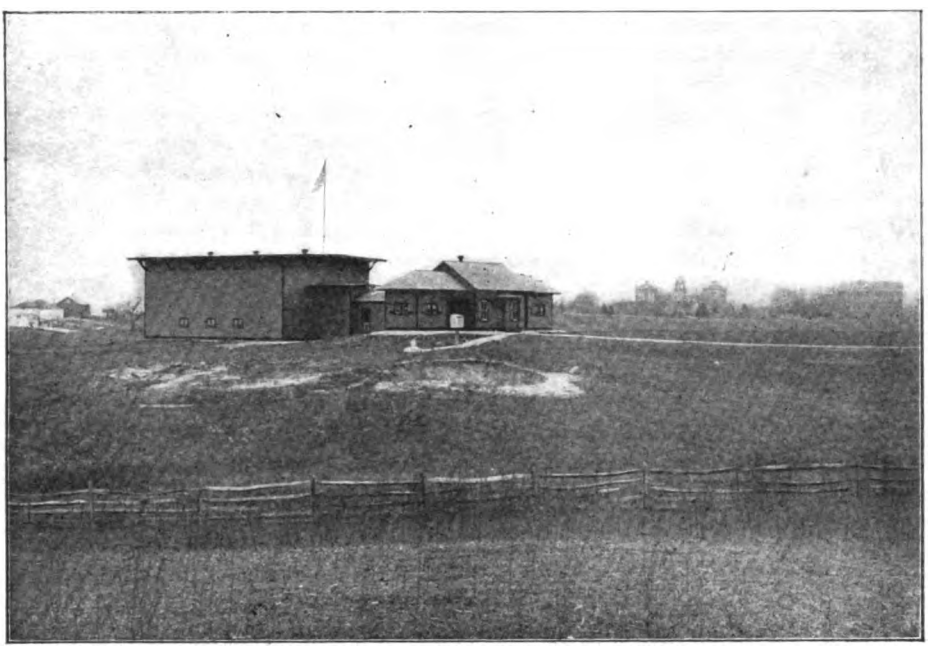
The sites for the first three observatories were selected after a careful personal examination of the regions by L. A. Bauer, that at Cheltenham in the spring and summer of 1899 and those at Sitka and Honolulu in the fall of 1900. Furthermore, as an additional precaution, J. A. Fleming was instructed that the selected sites were to be given another careful examination before the erection of the Sitka and Honolulu Observatories. In both instances the choice of the original location was confirmed. The site of the provisional magnetic observatory at Baldwin, Kansas, was se-



CHELTENHAM MAGNETIC OBSERVATORY (LOOKING NORTHEAST).

lected by W. C. Bauer and C. K. Edmunds. The four sites have thus far proven satisfactory.

The Site of the Cheltenham Magnetic Observatory.

A number of sites within a radius of about twenty-five miles of Washington City, in Virginia and Maryland, were examined, and the distribution of the magnetic elements tested before the final location was decided upon. The problem of establishing a standard magnetic observatory, which is expected to have a life embracing the period necessary for the general magnetic survey of the United States, and which is to be within convenient reach of the office of the Coast and Geodetic Survey at Washington, required special care, and several months were accordingly spent

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before a decision was reached. As far as uniformity in distribution of magnetism was concerned, the magnetic survey of Maryland by L. A. Bauer, under the auspices of the Maryland Geological Survey, had already indicated that the region to the southeast of Washington would probably furnish the best site in this respect, and the additional examinations resulted in the selection of that region.

An area examined toward the northwest of Washington, embracing the region about Gaithersburg, Md., where one of the international latitude stations is situated, exhibited such remarkable local disturbances, even within the small strip of land occupied by the latitude observatory, that it had to be rejected at once as the site of a normal magnetic observatory.

Suggestions regarding the selection of an island in the Chesapeake Bay received consideration, but this plan was abandoned in view of the possibility of disturbing influence from passing ocean steamers, and because of the difficulty of access at all times, and of transporting delicate instruments to such a place.

The site finally selected is on the grounds of the Maryland Reform School, about one mile and a quarter west of the railroad station at Cheltenham, reached from Washington or Baltimore via the Pennsylvania Railroad, changing cars at Bowie to the Pope Creek Railroad, a single-track branch of the Pennsylvania system. The traffic on this branch consists of two local passenger trains in the morning, one in each direction; two similar trains in the afternoon; and an occasional local freight train. The grounds of the reform school embrace about 800 acres, and are surrounded on all sides by farms of large extent. The site leased by the Coast and Geodetic Survey for an indefinite number of years comprises nearly six acres, and is situated on the highest land between the Potomac and Patuxent Rivers, the altitude being about 225 feet above sea level. Cheltenham consists principally of the buildings belonging to the reform school, about half a dozen frame cottages, two churches, and the railroad station.

As far as can be seen at present, there will be little inducement to run electric car lines into this region. From the site of the magnetic observatory an extensive view is obtained of the country round about, and the opportunities are favorable for the successful prosecution of all the work planned for this observatory.

THE SITE OF THE SITKA MAGNETIC OBSERVATORY.

After an inspection of various places in Southeastern Alaska, Sitka was decided upon as fulfilling most nearly the requirements above set forth. Owing to the rapid development of some of the Alaskan towns in recent years and the general prevalence of local magnetic disturbances, special care had to be exercised. Sitka has steamer communication with Seattle about once a week throughout the year.

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The site used by the Russians from 1843 to 1867 on Japonski Island is no longer suitable, and is occupied as a naval station. Owing to the mountains immediately back of Sitka it was not possible to get far away from the town. After a careful examination of various sites at Sitka by L. A. Bauer and J. A. Fleming, the site on a Government reservation near the new Russian cemetery was adopted. This site has since been set apart for the use of the Coast and Geodetic Survey by special executive order of the President of the United States. The magnetic observations made at the various sites examined revealed a sufficiently uniform distribution prevailing about Sitka.

THE SITE OF THE HONOLULU MAGNETIC OBSERVATORY.

Owing to the volcanic origin of the Hawaiian Islands, the requirements of a uniform magnetic distribution presented special difficulties. About a dozen sites on the island of Oahu were inspected and tested, and, usually, pronounced local disturbances within small areas manifested themselves in one or more of the magnetic elements. Sites on the Island of Hawaii were also inspected. As the facilities of communication are best for the Island of Oahu, on which Honolulu is situated, this island received first consideration. Observations made by L. A. Bauer and J. A. Fleming at various points on the immense coral plain to the west of Honolulu and Pearl Harbor, while indicating small irregularities in magnetic distribution, served to mark out a site within which sufficient uniformity was secured.

It was necessary to locate the observatory beyond any possible influence likely to arise from the large works to be erected at Pearl Harbor by the United States Navy Department and to provide against the possibility of electric-car communications of Pearl Harbor with Honolulu; also the observatory had to be sufficiently removed from the existing and contemplated mills and power plants of the neighboring large sugar-cane plantation and of the adjacent sisal plantation. This necessitated putting the observatory over two and one-half miles from the nearest village, in the midst of the coral plain, where, because of the absence of sufficient amount of tillable soil, the danger of encroachments from the plantations is minimized. This coral plain is mainly used at present as a cattle ranch. The area of the site leased from the ranch company is 4.3 acres. The site is about two-thirds of a mile from the railroad station, Sisal, on the Oahu Railroad, a single-track narrow-gauge road, the station consisting of the house occupied by the manager of the sisal plantation. From this station communication is had direct with Honolulu, distant twelve and one-half miles in an air line and twenty miles by railroad.

THE SITE OF THE BALDWIN MAGNETIC OBSERVATORY.

This observatory, as already stated, was intended to be in operation for a brief period while the magnetic survey of the States in the vicinity

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was in progress, and no special buildings were erected, but such as already existed were adapted for the work.

Baldwin is a small college town, the site of Baker University. This place, being surrounded on all sides by large farms and being centrally situated, offered a good place for a temporary observatory. Owing to the international magnetic work begun in January, 1902, and because of delay in completing the magnetic survey of the neighboring States on account of the difficulty experienced in obtaining new magnetic outfits promptly, it has been necessary to continue the observatory longer than was originally contemplated.

II. CONSTRUCTION OF THE MAGNETIC OBSERVATORIES.

No attempt at architectural display in the construction of the buildings was made. In view of the uncertain life of a magnetic observatory, they were designed simply to fulfill as adequately as possible the requirements of the work without going to any unnecessary expense.

The general design of the three observatories, Cheltenham, Sitka, and Honolulu, planned by J. A. Fleming under the direction of L. A. Bauer, is the result of a careful study of past and existing plans and methods. This study indicated that, after the selection of sites well removed from all present and probable future local magnetic disturbance, the chief requisites desirable were: First, the elimination in construction of all materials showing any magnetic properties, even in the case of the variation observatory; second, the arrangements for absolute and variation instruments to be such that the mutual interaction of the various instruments would be inappreciable; third, the buildings for measurement of absolute values to be such as to admit of a number of simultaneous determinations without danger of appreciable mutual interaction of magnets of the various instruments; fourth, the building for variation observations to be constructed so as to have as nearly a uniform temperature throughout the year as possible, without employing extensive means for heating or cooling the rooms; fifth, the variation observatories to have accommodations for at least two sets of instruments—one eye-reading and one self-registering set—and that they be of a size sufficient to meet all reasonable demands now and later.

CONSTRUCTION OF THE CHELTENHAM MAGNETIC OBSERVATORY.

As a result of the *first condition* imposed above, the two structures, variation observatory and absolute observatory, consisting of an office flanked by two wings for the absolute observations, were built entirely of wood, and copper nails were used exclusively except when wooden pins could be substituted in framing. The greatest difficulty was found in selecting non-magnetic material for foundations and piers, and ten samples of building stones were tested with the Adie magnetograph and all found more or less unsatisfactory. To overcome this difficulty, the

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foundations were designed to be two and one-half feet deep of rubble work, surmounted by a grillage of eight by eight inch timbers, five pieces high.

Fortunately, at Cheltenham a marble was procurable practically free from magnetic properties. The foundations of the variation observatory and of the piers extending to floor line were constructed of marble rub-

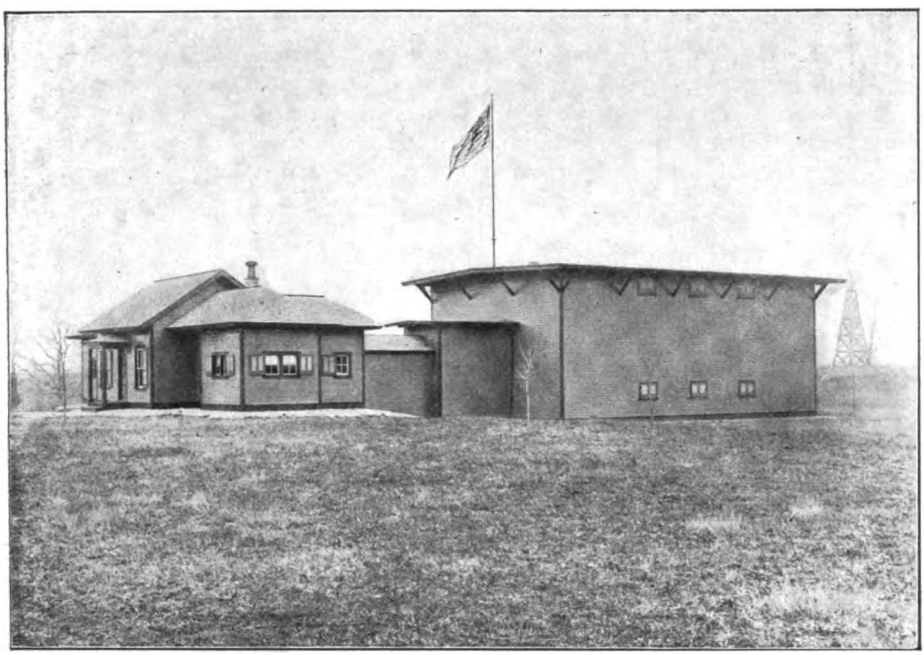

FIGURE 2. CHELTENHAM MAGNETIC OBSERVATORY (LOOKING NORTHWEST.)

ble work. Above the floor line some of the piers were built up to the desired height of cut marble pieces twelve and eight inches thick, the separate pieces being doweled together with three five-eighths inch copper dowels set in plaster of paris. Other piers put in later are of sandstone, carefully tested. The instrument supports in the west wing of the absolute observatory were made temporarily of cedar posts of suitable heights inclosed with tongue-and-groove casing and capped with hardwood blocks. In the east wing of the absolute observatory the instrument piers are of non-magnetic sandstone.

The chimney for the office, being fairly well removed from observation centers, was designed to be of a white brick which from tests was found to have a very small magnetic effect; a stone rubble construction would have been of inconveniently large section. For heating the office a wood stove of soapstone slabs was designed; this did not prove satis-

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factory and was replaced by a copper-covered stove lined with fire brick. The question of hardware furnishings was also a source of difficulty, as nearly all of the so-called "brass" fittings were found to have iron parts which made it necessary to place special orders for the greater part of this material.

The *second condition* made it preferable that the buildings for absolute and variation observations should be separate and distinct, though questions of practical convenience required that they be as close together as possible without danger of appreciable magnetic interaction between the various instruments. Rough calculations of the mutual actions between a C. & G. S. magnetometer and the Adie instruments for varying intervening distances were made and the effect was found to be practically zero, for the instruments mounted forty feet apart, and the plans were made accordingly. The two buildings were connected by a covered wooden corrider.

In fulfilling the *third condition* the general plan already used by the Coast and Geodetic Survey at San Antonio, Texas, seemed best to follow. This consisted in erecting two buildings for absolute determinations, attaching the same as wings on either side of the office and connecting them by passageways. The doors from the office to these wings and also the rear door of the west wing of the absolute observatory have glass panels, so that communication by signal, or otherwise, from one wing to the other and to parties in tents outside can be conveniently and readily made. The east wing of the absolute observatory has a bay window extension on the north side to accommodate the Wild-Edelmann Observatory declinometer.

The *fourth condition* requires that either some sort of insulation be provided if the variation observatory be erected above ground, or that the general use of an underground construction be followed. The success in the matter of uniform temperature conditions attained at the Dutch Observatory at De Bilt, as well as the generally unsatisfactory conditions prevailing in most underground observatories because of moisture encountered in such structures, confirmed the opinion that a building above ground could be built so as to satisfy temperature conditions as well, or nearly so, as an underground structure, and would at the same time have the advantages of greater economy, convenience, and accessibility.

The choice of insulating packing for the walls was a question of prime consideration. The manufactured insulating materials on the market, on inquiry and examination, were found to contain more or less iron in their composition, and at the same time would have involved a much greater cost than permissible when used in such quantities as required. After a careful consideration of the non-magnetic materials available, carefully dried sawdust was decided upon as best adapted to the existing conditions.

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In deciding upon the necessary thickness of insulating wall to reduce annual mean temperature range to within 4° C to 5° C, Fourier and Poisson's formula,

$$\log \frac{\Delta_0}{\Delta_p} = p \log e. \sqrt{\frac{\pi}{TK}} \qquad (1)$$

as found in Wild's article,[1] was adopted for a working basis. The significance of the various symbols is as follows: Δ_0 = external range of temperature in a time T expressed in minutes, Δ_p = range of temperature in the same time T in a room surrounded by a thickness of p cm.

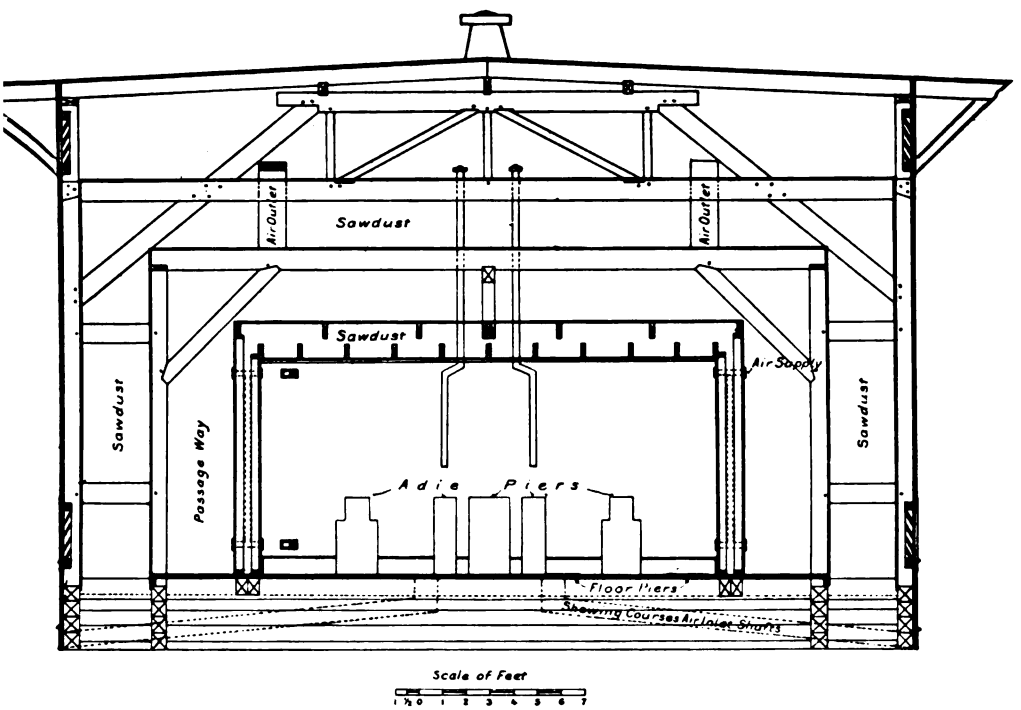

FIGURE 3. SECTION OF VARIATION OBSERVATORY, ADIE ROOM, CHELTENHAM MAGNETIC OBSERVATORY.

of insulting material, e = base of natural logarithms, and $K = \frac{k}{c}$ = what might be called the heat constant of the insulator, being a relation between its heat conductivity and its specific heat. According to Forbes, K for pine sawdust is 0.021, for pine across the grain 0.018, and for pine along the grain 0.053, whence it was assumed that for a wall packed with

[1] T. M., Vol. IV, p. 191.

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sawdust, with such bracing and tying timbers as might be necessary. $K=0.035$. Reducing formula (1) with this value, we have for:

$$T=1 \text{ day}; \quad \log \Delta_p = \log \Delta_o - 0.1084\, p. \qquad (2)$$

$$T=1 \text{ year}; \quad \log \Delta_p = \log \Delta_o - 0.0057\, p. \qquad (3)$$

The mean daily range at Cheltenham was assumed to be 10° C., with a mean annual range of 25° C. Substitution of $\Delta_o=10°$ in (2) for values of p from 30 to 100 cm. indicated that under ideal conditions the interior mean daily range for such thicknesses of sawdust insulation would scarcely be an appreciable quantity. In determining upon a proper thickness to sufficiently reduce mean annual range, the curves were constructed from values of Δ_p derived by substitution in (3) of $p=30, 40, 50— \ldots 130$ cm. with $\Delta_o=25°$, 20°, and 11° (the last two being the values of Δ_o for Sitka and Honolulu respectively, as furnished by the United States Weather Bureau). Thus, for a wall with sawdust packing 4 feet thick, Δ_p for Washington, according to the curve, would be about 5°.1 without artificial heating or cooling, on the assumption of ideal conditions. Perfect conditions were, of course, practically impossible, but further insulation precautions were made, as noted hereafter, so as to bring about the best possible results.

The wall insulation of the variation observatory is as follows (see Figure No. 3): Beginning at outside of building, pine weatherboarding, 8-ply building paper, 1-inch pine sheathing, 8-inch air shaft, 1-inch pine sheathing, 8-ply paper, 3 feet pine sawdust, 8-ply paper, seven-eighths inch pine ceiling, 3 feet two inches air space of passageway, seven-eighths inch pine ceiling, 8-ply paper, 1 foot pine sawdust, 8-ply paper, seven-eighths inch pine ceiling. Slat ventilators or louvre windows are so arranged and provided with closely fitting shutters that during the winter the 8-inch air shaft referred to can be made practically air-tight, while during summer when opened these tend to admit of the passage and circulation of a cooling draft around building. The insulation beginning at the roof and going down is: Gravel and asphalt pitch roof, 1-inch pine sheathing, 3 feet 8 inches air space communicating with 8-inch air shaft around building, and provided with six louvre windows with close-fitting shutters as on those at the bottom of the air shaft, 1-inch rough pine floor, 3-foot filling of pine sawdust, 8-ply paper, seven-eighths inch pine ceiling, 3-foot air space above rooms, 1-inch rough pine floor, 1 foot 6 inches pine sawdust, 8-ply paper, seven-eighths inch ceiling. Insulation from bottom of foundation is 2 feet 8 inches of earth, 6-inch to 8-inch layer of screened gravel, about 3 feet pine sawdust, 1-inch pine under floor, 8-ply paper, seven-eighths inch pine tongue-and groove floor.

The greatest difficulty in obtaining the desired results lay in the necessity of providing openings through the walls for the ventilation of the rooms and for the means of ingress and egress. Four shafts, each

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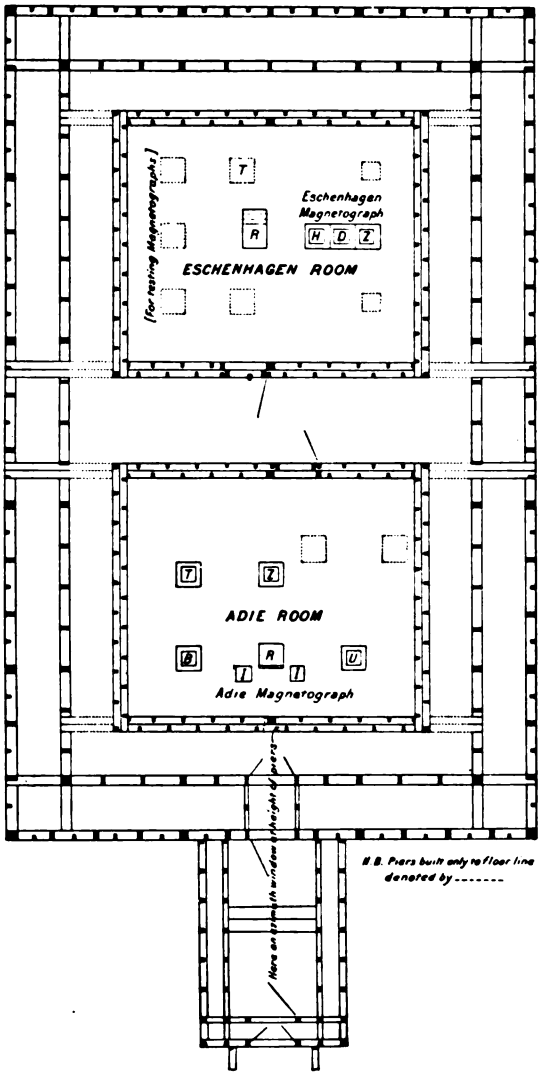

FIGURE 4. GROUND FRAMING PLAN OF VARIATION OBSERVATORY, CHELTENHAM MAGNETIC OBSERVATORY.

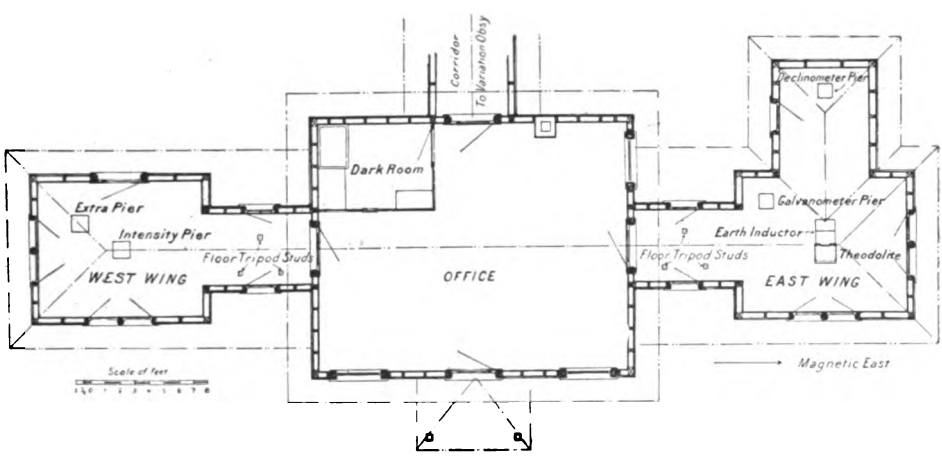

FIGURE 5. GROUND PLAN OF ABSOLUTE OBSERVATORY, CHELTENHAM MAGNETIC OBSERVATORY.

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5 by 10 inches and about 16 feet long, furnish the air supply to the passageway, through wooden floor grates. These are provided with heavy rabbeted shutters made to fit very closely and fitted with refrigerator fasteners, so that they may be made air-tight. They are also provided at inlet with copper wire screens of double thickness to break force of wind blowing toward opening and to keep out such vermin as field mice. Ventilation of passageway is effected by four shafts opening into air space below the roof, each 6 by 10 inches and about 16 feet long, provided with close-fitting slides. Ventilation of air space below the roof is effected by three 14-inch copper "Star" ventilators. By the judicious use of these air ducts and ventilators, the danger of direct conduction of temperature changes through the shafts can be entirely eliminated. Ventilation of the magnetograph rooms from and into the passageway is effected in each room by four 3-inch square vertical shafts in the sawdust packing, having inlet or outlet just below the ceiling or above the baseboard, according to the arrangement of four closing slides provided for each. To carry off gases of combustion from the lamps of the magnetograph, 3-inch copper ventilators are provided.

Entrance into the building proper is had through a vestibule on the south side, as shown in Figures Nos. 1, 2 and 4, 10 feet by 13 feet 8 inches outside dimensions. The walls of the entrance are built like those of the main building, without the air shaft and with only two feet of sawdust packing. The outside door can be closed before opening a second door in a small entrance hall, which is 6 feet wide and 11 feet long; from this room a third door leads into an opening in the sawdust packing, whence a fourth door opens into the passageway around the rooms. In placing these doors, particular care was taken to make them close-fitting. Entrance into either of the magnetograph rooms is to be had only from the hall between the two rooms through 8-inch refrigerator-patterned doors packed with sawdust.

The diurnal range of the temperature was thus reduced at Cheltenham to a matter of a few tenths of a degree, and, in fact, it is believed that even this small variation will be eliminated as soon as some other source of light than the present lamps has been introduced. It has been repeatedly found that any sudden change of temperature which may amount to 50°–60° F. outside only makes itself felt gradually inside, and then does not amount to much over 0°.5, and may even be less than this amount. The annual range has been converted into a gradual progressive change, for which allowance can easily be made, and amounting to between one-half and one-third of what it would be outside.

The *fifth condition* imposed by the contemplated use of the Adie magnetograph as the eye-reading instrument and reserve magnetograph, made necessary two magnetograph rooms in the variation observatory, and that they be placed as far apart as economy of construction

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would permit. The rooms are each 16 feet by 19 feet 6 inches, these dimensions giving ample space for the accommodation of the eye-reading Adie instruments in the south room, and for both the regular set of Eschenhagen self-registering instruments and a test set in the north room. The hallway between the two rooms is 5½ feet wide. (Figure No. 4.)

The outside dimensions of the variation observatory are 36 feet by 56 feet by 24 feet high, with entrance 10 feet by 13 feet. The outside dimensions of office are 18 feet by 22 feet, with two 5 feet by 7 feet passages leading to two wings for absolute observations, each 10 feet by 12 feet, thus making the total length of the absolute observatory, inclusive of the office, 60 feet. As already stated, the east wing of the absolute observatory has a bay-window extension of 6 by 7½ feet on the north side. (Figure No. 5.) The materials used were about 90 tons of building marble for foundations and piers, 85,000 feet of lumber, a trifle over one ton of copper nails, and something more than 190 tons of sawdust and shavings for insulation. No satisfactory bid from contractors for erecting the buildings having been received, the construction was placed in the hands of the designer, J. A. Fleming. The total cost of the buildings, including masonry and pier work, was something less than $6,900, which is $2,500 less than the lowest bid received. Some subsequent additions (piers, bay window, and covered corridor) have increased the cost about $500.

From Figure No. 4 it will be seen that provision was made, by the insertion of an azimuth door in the south wall of the Adie room of the variation observatory, for sighting from a point inside, through the corridor and office, on a distant azimuth mark whenever absolute observations are made inside the variation observatory. The arrangement of the absolute instruments is on a straight line passing east and west through the entire absolute building.

Construction of the Sitka Magnetic Observatory.

On account of the swampy condition of the ground at this observatory site, charred wooden posts, coated with tar and gravel and set in cement, were used instead of a stone-work foundation. The piers are similar in construction, and were provided with hardwood caps suitable to support the instruments. As a result of the prevailing moisture at Sitka it was necessary to replace these hardwood caps by marble slabs. The posts are inclosed above the floor line with tongue-and-groove casing.

A small frame dwelling house situated opposite the selected site was leased as an office building, and the absolute observatory, 10 by 12 feet in size, was placed in its proximity.

The general construction of the variation observatory is similar to that at Cheltenham, save that a pitched roof is provided, the greater

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height so obtained offering a greater draft through the louvre windows at the sides.

The wall insulation was designed to secure the results desired at Cheltenham observatory, namely, a mean annual range of about 5° C. The insulation is as follows: Beginning at the outside of the building, pine weatherboarding, two thicknesses of 4-ply paper, 1-inch pine sheathing, 2-inch by 6-inch studding, forming air spaces connected by auger holes at bottom through studding, 1-inch sheathing, two thicknesses of 4-ply paper, 2 feet 4 inches of sawdust packing, two thicknesses

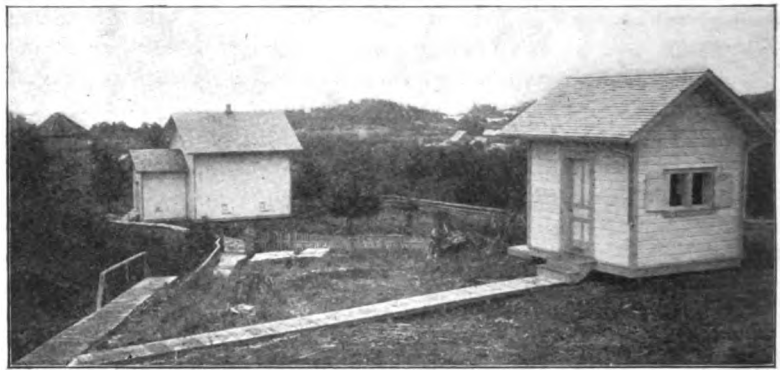

FIGURE 6. SITKA MAGNETIC OBSERVATORY, VARIATION AND ABSOLUTE BUILDINGS.

of 4-ply paper, seven-eighths inch pine ceiling, 2 feet 2 inches air space of passageway, save on west side, where it is 2 feet 10 inches, seven-eighths inch pine ceiling, two thicknesses of 4-ply paper, 11 inches of sawdust packing, two thicknesses of 4-ply paper, seven-eighths inch pine ceiling. Louvre windows with shutters, as at Cheltenham, are provided on the sides for the 6-inch air space. The insulation beginning at the roof and going down is: Shingle roof, attic air space, two thicknesses 4-ply paper, 1-inch rough pine floor, 2 feet 4 inches of sawdust, 1-inch rough pine floor, 2-inch air space, two thicknesses 4-ply paper, seven-eighths inch pine tongue-and-groove ceiling, 2 feet air space above magnetograph room, two thicknesses of 4-ply paper, 1-inch rough pine floor, 13 inches of sawdust, 1-inch rough pine floor, 2-inch air space, two thicknesses of 4-ply paper, seven-eighths inch ceiling. The insulation from bottom up is: One-inch rough pine floor, two thicknesses of 4-ply paper, 2 feet 6 inches of sawdust, 1-inch pine under floor, two thicknesses of 4-ply paper, seven-eighths inch tongue-andgroove floor.

The ventilation system is somewhat improved over that at Cheltenham in that the air supply is admitted first into the entrance vestibule by two 6-inch by 8-inch by 8-foot shafts in the walls, thence into the

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passageway through two 5-inch by 8-inch shafts, instead of there being direct communication from the outside to the passageway. The supply of air to the magnetograph room is admitted from the passageway by three sets of ventilators. These consist of 4-inch square vertical shafts in the walls, with openings at the bottom and top, both into the inner room and into the passageway, the openings not being opposite each other, thus preventing entrance of light and dust. Ventilation of lamps from magnetograph room is effected by 3-inch zinc tubes to the attic space. Air communication from the passageway to the air space below the roof is effected by two horizontal square shafts, 8 by 8 inches, and about 6 feet long. Ventilation of the attic is effected by 20-inch copper ventilator.

As it was expected that both the eye-reading and self-recording instruments would be of the small Eschenhagen type, it was not necessary to provide two magnetograph rooms, as both sets could be accommodated, with the arrangements of piers shown in the plan, in one room 11½ by 14½ feet. The vestibule is 6 by 9½ feet, inside measure.

The outside dimensions of the variation observatory are: 24 by 27 feet, with an entrance 9½ by 12 feet. The absolute observatory is 10 by 12 feet. About 35,000 feet of lumber and 3,000 sacks of sawdust were used in the construction. The buildings were constructed under contract with James P. Jorgenson, of Juneau, Alaska, for $3,450. H. M. W. Edmonds, Magnetic Observer, Coast and Geodetic Survey, supervised the construction.

Construction of the Honolulu Magnetic Observatory.

Owing to the isolation of this station, an office with quarters for the observer had to be provided in addition to the two observatory buildings. On account of the excessive cost of building in the Hawaiian Islands the original plan to have this observatory similar to that at Sitka was abandoned and, in view of the more equable climatic conditions, the passageway was dispensed with, so that the instrument room is entered directly from the vestibule. The foundations and piers for both the absolute and the variation observatories are constructed of the coral rock which abounds in the immediate neighborhood which was found to be practically non-magnetic in character.

As the office had also to be used for living quarters where an uncertain amount of iron was likely to accumulate, it seemed best to remove it to some distance from the observatory. Owing to natural conditions of the site the distance between office and observatories is 450 feet.

As at Sitka, a pitched roof was provided. The air supply and outlet are also similar to those at Sitka with such exceptions as are necessary because of the omission of the passageway. The louvre windows to a 6-inch air space in the outer wall were made continuous around the bottom of the building, but were not provided with blinds because the

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small annual range of temperature rendered them unnecessary. The upper louvre windows were omitted and a lower cornice board was used, thus allowing direct outside communicatian to an air space under the roof made by covering the underside of the 6-inch rafters with heavy 3-ply building paper well battened on. An outlet from this 6-inch air shaft and the attic was made through an open ventilator, as shown by the illustrations. This arrangement was intended to accomplish the same result as the passageway, and was better adapted to the prevailing climatic conditions.

The wall insulation is based on the same principles as at other stations. The insulation is as follows: Beginning at the outside of the building, pine weatherboarding, 3-ply paper, 6-inch air space, 1-inch pine sheathing, 3-ply paper, 2 feet 2 inches of sawdust, 3-ply paper, seven-eighths inch tongue-and-groove ceiling. The insulation, beginning at the roof and going down, is: Shingle roof, 6-inch air space, 3-ply paper, attic air space,

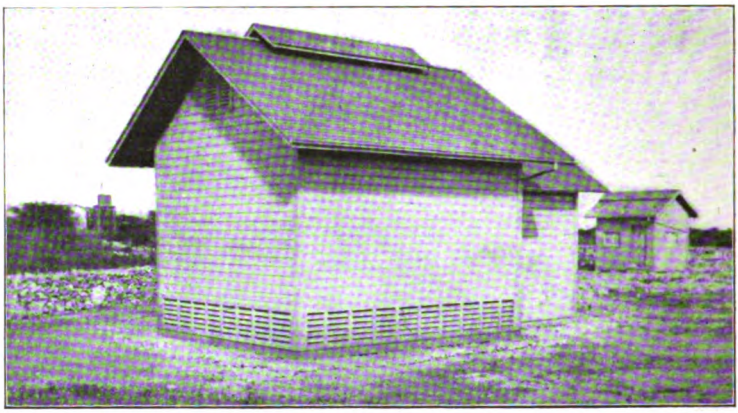

FIGURE 7. HONOLULU MAGNETIC OBSERVATORY.

3-ply paper, 2 feet of sawdust, 1-inch rough floor, 2-inch air space, 3-ply paper, seven-eighths inch tongue-and-groove ceiling. The insulation from the bottom up is: 3 to 4 inches of broken coral rock, 2 feet 2 inches of sawdust, 3-ply paper, seven-eighths inch tongue-and-grove floor.

As at Sitka, accommodations for two sets of instruments were provided in one room, 12½ by 14½ feet. The vestibule is 6 by 9½ feet, inside measure.

The outside dimensions of the variation observatory are 18 by 20 feet, with an entrance 9½ by 12 feet. The absolute observatory is 10 by 12 feet. The office is 12 by 16 feet, with a porch 6 by 12 feet, with a basement room for storage purposes, etc., 12 by 22 feet. The buildings were constructed under contract with Philip Savary, of Honolulu, H. I., for $2,450. The work of construction was supervised by the designer, J. A. Fleming, who also installed the instruments.

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III. EQUIPMENT OF THE OBSERVATORIES.

CHELTENHAM MAGNETIC OBSERVATORY.

Variation instruments: Eschenhagen-Toepfer magnetograph as the principal photographic set and an Adie magnetograph formerly mounted at Los Angeles, Cal., from 1882 to 1889, and at San Antonio, Tex., from 1890 to 1895, this magnetograph having telescopes and scales for eye readings. It is the intention ultimately to use the Adie instrument simply for eye-reading observations, retaining, however, the photographic arrangement so that it can be put into function either to prevent loss of record, as for example, during adjustments of the Eschenhagen magnetograph or for the purpose of obtaining, in special investigations, a duplicate record with a totally different instrument. The plan of the Observatory (Figure 4) shows how the two magnetographs are mounted in separate rooms.

Absolute instruments: A large observatory Wild-Edelmann declinometer, earth inductor, and magnetometer, to determine, respectively, the declination, dip, and horizontal intensity, the instruments being always in place and ready for observations at any time. The declinometer, earth inductor, galvanometer, and large theodolite are mounted in the east wing of the absolute observatory (Figure 5), whereas the magnetometer for horizontal intensity observations (adapted also for secondary magnetic declination determinations with short magnet, when needed), is mounted in the west wing of the observatory (Figure 5). A set of field magnetic instruments also forms part of the outfit.

Accessories.—Atmospheric electricity instruments, meteorological instruments, two chronometers, thermographs, etc.

[In view of the fact that a Milne seismograph is now mounted at the Johns Hopkins University, Baltimore, about 40 miles from Cheltenham, the mounting of a seismograph at Cheltenham has been deferred temporarily. It is hoped soon to be able to install the necessary apparatus for earth-current observations, for which the Cheltenham site is admirably suited. It is the intention ultimately to carry out at this observatory all the work forming an essential part of a fully equipped, first-class magnetic observatory.]

SITKA MAGNETIC OBSERVATORY.

Variation Instruments.—Eschenhagen-Toepfer magnetograph, to be supplemented also with eye-reading instruments; the vertical intensity variometer is to be supplied by Schulze, of Potsdam.

Absolute Instruments.—Eschenhagen-Tesdorpf magnetometer, dip circle, and vertical force magnetometer; also, for field use, one Coast and Geodetic Survey magnetometer and an additional dip circle.

Accessories.—Meteorological instruments, two chronometers, thermographs, etc. This list is to be supplemented by a seismograph and atmospheric and telluric electricity instruments.

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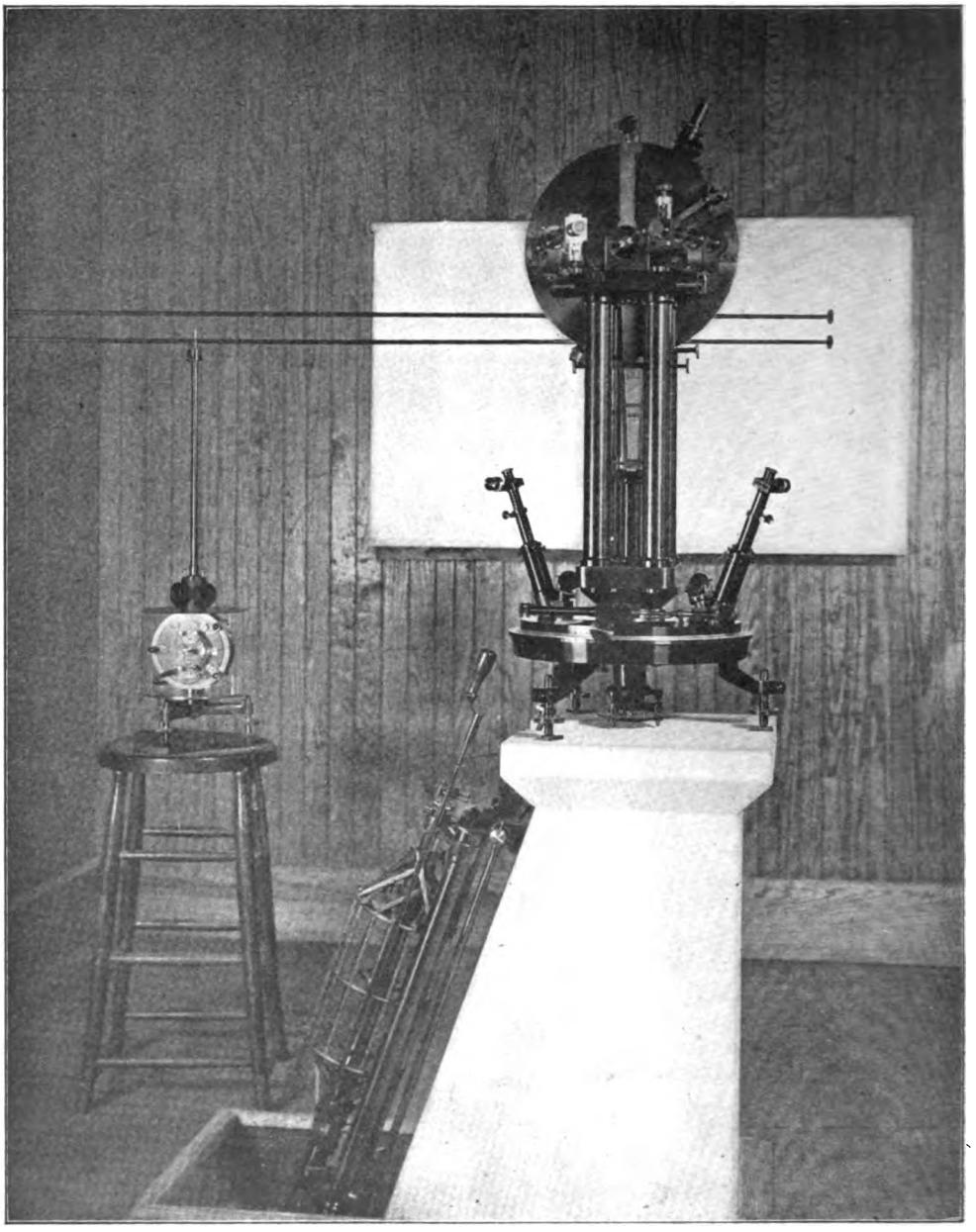

FIGURE 8. LARGE WILD-EDELMANN EARTH INDUCTOR, CHELTENHAM MAGNETIC OBSERVATORY.

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HONOLULU MAGNETIC OBSERVATORY.

Variation Instruments.—Eschenhagen-Toepfer magnetograph, to be supplemented by eye-reading instruments. The vertical intensity variometer is to be supplied by Schulze.

Absolute Instruments.—Wild-Edelmann field magnetometer, with earth inductor and galvanometer, and a complete set of magnetic instruments for field use.

Accessories.—Meteorological instruments, two chronometers, thermographs, etc., to be supplemented by atmospheric and telluric electricity instruments, and a seismograph.

BALDWIN MAGNETIC OBSERVATORY.

Variation Instruments.—Eschenhagen-Toepfer magnetograph. The vertical intensity variometer is to be supplied by Schulze.

Absolute Instruments.—Cooke (India Magnetic Survey pattern) magnetometer and Casella dip circle. Also one set of field instruments.

Accessories.—Atmospheric electricity instruments, meteorological instruments, two chronometers and thermographs. This list to be supplemented by a seismograph.

The instruments and their mounting will be described in detail and illustrated in the publications of the results of the various observatories.

IV. GEOGRAPHIC POSITIONS OF AND MAGNETIC ELEMENTS AT THE MAGNETIC OBSERVATORIES.

Approximate magnetic Elements of the magnetic observatories for the period January–June, 1902.

Observatory.	Latitude north.	Longitude west of Greenwich.	Approximate altitude.		Declination.	Inclination	Horizontal intensity in C.G.S. units.	Observer in charge July 1, 1902.
	° ′	° ′	*Feet.*	*Met.*	° ′	° ′		
Cheltenham	38 44.0	76 50.5	235	72	5 06 W	70 23	0.2019	L. G. Schultz.
Baldwin	38 47.0	95 10.0	1100	335	8 23 E	68 36	.2197	W. F. Wallis.
Sitka	57 02.9	135 20.2	50	15	29 50 E	74 48	.1541	H. M. W. Edmonds.
Honolulu	21 19.2	158 03.8	50	15	9 17 E	40 15	.2925	W. Weinrich, jr.

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TROMHOLT'S CATALOGUE OF NORWEGIAN AURORAS.[1]

CLEVELAND ABBE.

No one has labored more faithfully to elucidate the problems of the aurora than Dr. Sophus Tromholt, of Rostock, Norway, who died April 17, 1896.

Among his most important works was that done when he, in 1882–3, personally occupied a station at Koutokeino in Finmark, Norway, in order to study the auroras observed by the Norwegian party at Bossekop, Norway, and the Finnish party at Sodan-Kyla. Tromholt was about sixty-six miles south of Bossekop and two hundred miles northeast of Sodan-Kyla, and observations of the auroras were made at all three stations at prearranged moments of time, for the express purpose of determining their altitudes. The results of these special observations have as yet been only partially published.

In Petermann's Mittheilungen, 1892, Vol. XXXVIII, Tromholt published a preliminary report on two important works that he then had in hand, namely, a complete catalogue of the observations of auroras, as recorded by Norwegian observers since the year 1594, with special descriptions of the more important auroral displays and a general analysis of the reports. As it seemed likely that there would be a long delay in the publication of this important work, the abstracts given by Tromholt in this preliminary communication were extremely welcome. My personal interest in the matter even led me to offer to supervise the publication in America of the original work, since the author had failed to find a publisher in Europe, but his early death closed our negotiations in this respect, and it appears that his manuscript was subsequently given, by his widow, to his friend J. Fr. Schroeter for the purpose of publication in Norway if possible. This desire has now been realized, and the publication at the joint expense of the Academy of Sciences at Christiania and the "Fridtjof Nansen Fund," as recommended by Prof. Dr. Mohn, is a valuable addition to our knowledge of the aurora borealis.

The volume is a quarto of 422 pages. Besides the preface by Schroeter, there is also a preface apparently about as prepared by Tromholt, from which we learn that he began the work of making this collection in 1879, and did not shrink from the great labor of examining general historical and archæological works, public and private libraries, and the archives of about a dozen public institutions, including the University Library at Leipsic. Especial attention was given to Norwegian

[1] Catalog der in Norwegen bis Juni 1878 beobachteten Nordlichter zusammengestellt von SOPHUS TROMHOLT.

Herausgegeben von J. FR. SCHROETER. Kristiania, 1902. Pp. XXIII+422. 24 x 31 cm.

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newspapers, and in all cases the complete records of details were copied out. The dates are always reckoned, as in astronomy, from noon to noon; the four subdivisions of Norway are: I, north of 68° 30′; II, between 68° 30′ and 65°; III, between 65° and 61° 30′. The total number of stations from which observations have been gathered is 216, and the total number of sources of information referred to in the catalogue is about 300.

Under the editorship of Schroeter the material collected by Tromholt has been judiciously sifted, and apparently nothing has been published that is not a distinct addition to exact knowledge. Especially must we approve of Schroeter's good judgment as an editor in restricting the publication of detailed descriptions, partly because so many are given in the publications of the International Polar Research, 1882–3, by expert physicists, that nothing more would seem to be necessary; partly because there is abundant reason to think that the same aurora presents different aspects to observers a few miles apart, so that the mass of details must be useless until we understand more about the location and origin of the phenomena.

The list of auroras (Catalogue D) begins with September 27, 1594, and ends with April 22, 1878, covering 210 pages and giving about 9,000 observations on nearly 6,000 different auroral dates. For each date is given the age of the moon, the place and time of observation, a few words of description, and a reference to the source of information. In the second section, special descriptions are given of suspected auroras, from 1550 to 1569, and of auroras proper from 1739 to 1878. In the third section, Table A gives the monthly and annual sums of the days on which auroras were observed somewhere in Norway. The auroral year, like the snow year, is reckoned from July to June inclusive. The annual sums are then transformed into smoothed numbers by the formula $1/10\ (a+2b+4c+2d+e)$. The annual sums are also given for each of the four sections into which the author subdivides the area of Norway. On page 352 these annual sums, from 1761 to 1878, are combined in one total representing the monthly distribution of 5,891 days with auroras. This computation is given for each of the four subdivisions as well as for all Norway. The monthly sums are also converted into comparable percentages by reduction to a uniform summation of 1,000, whence it appears that in the northernmost division of Norway the annual periodicity shows a maximum at the winter solstice, whereas in the southernmost section two maxima occur corresponding to the equinoxes. Therefore, in the northern portion of Norway the annual periodicity is of the same character as in the Arctic regions generally. The southern division of Norway shows an annual period similar to that prevailing in middle latitudes. A combination of all the records of Tromholt in Norway and Rubenson in Sweden is given on

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pages 353-414, for the years 1722, March 4, to 1878, April 22. The study of the geographical distribution of these observations shows again a maximum in January, in the northern regions, and maxima about September 21st and March 21st in the southern regions.

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It is not likely that this great work of Tromholt's, taken in conjunction with its predecessors, exhausts all accessible European records, but it goes a long way towards preparing the way for a renewal of the comprehensive studies of the geographical and chronological distribution of auroras that were initiated by Fritz fifty years ago.

U. S. Weather Bureau,

Dec. 18, 1902.

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LORD KELVIN.

Sir William Thomson, the first Lord Kelvin, the son of James Thomson, LL. D., Professor of Mathematics at Glasgow, was born at Belfast, Ireland, June 26, 1824. He was a very precocious child, entered Glasgow University when only eleven years of age, matriculated at St. Peter's College, Cambridge, when seventeen, and the same year wrote a paper, entitled "Uniform Motion of Heat in Homogeneous Uniform Bodies," in which he defended the work of Fourier against some adverse criticism directed against it. The following year appeared his article on the "Linear Motion of Heat."

In 1845, at twenty-one years of age, he graduated from Cambridge as second wrangler and first Smith's prizeman; and was at once elected Fellow of St. Peter's College, which position he retained until his marriage in 1852; in 1872, under a new statute, he was elected to the Fellowship he now holds at St. Peter's. In 1845 also appeared "Elementary Laws of Static Electricity," in which he defended Coulomb's theory of the fundamental laws of electric attraction and repulsion against the attacks of Snow Harris and Faraday, and showed that the experiments of these men so far from being opposed to Coulomb's theory, were, when correctly interpreted, confirmatory of it.

He studied chemistry in Paris under Regnault. In 1846, he was elected to the chair of Natural Philosophy at Glasgow, to succeed Dr. Meikelham. From 1846–1851, he was editor of the Cambridge and Dublin Mathematical Journal, and about the same time he developed his theory of electrical images. In 1849 appeared his first paper on Thermodynamics. It was a critical account of Carnot's memoir of 1824, "Reflexions sur la Puissance Motrice du Feu," and embodied Joule's results on the "Mechanical Equivalent of Heat." It was this paper which first brought Carnot's work into prominent notice. At this time Kelvin believed in the caloric theory of heat. Shortly after this he showed how to define the absolute thermodynamic scale of temperature, and in 1852, in his paper on the "Secular Cooling of the Earth," he announced the principle of the "dissipation of energy."

In 1855 he delivered the Bakerian lecture on "Electrodynamics of Qualities of Metals," in which he called attention to what he called the "electric convection of heat." He now became interested in submarine telegraphy and devoted most of his time from 1857–1879 to this subject. He was electrician of the Atlantic cable of 1857–1865, of the French Atlantic cable, the Brazilian and River Platte, the West Indian, and the Mackay-Bennett Atlantic cables. During this period he invented several electrical instruments, the best known of which are the mirror galvanometer and the siphon recorder.

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In 1867 appeared the first edition of his Natural Philosophy. He was President of the Edinburgh meeting of the British Association in 1871, President of the Royal Society in 1890–1895, three times President of the Royal Society of Edinburgh. He was knighted in 1866, and was created Baron Kelvin in 1892. In 1896 was celebrated the fiftieth anniversary of his accession to the chair of Natural Philosophy at Glasgow. He was twice married.

His work touches all departments of Physics; he calculated the size of atoms, determined the rigidity and age of the Earth, promulgated the vortex atom theory, devised a new form of mariner's compass, a navigational sounding machine, etc. He was much interested in navigation, and gave a method for correcting a compass for the magnetism of the ship, and published "Tables for Facilitating the Use of Sumner's Method at Sea." His original papers on mathematical and physical subjects have been reprinted in three series; viz., Electrostatics and Magnetism, 1 volume; Mathematical and Physical Papers, 3 volumes; Popular Lectures and Addresses, 3 volumes.

It is not possible to enumerate here all of the many honors showered upon him at home and abroad, nor to make specific mention of his contributions to the subjects of terrestrial magnetism and atmospheric electricity.

Helmholtz says of him: "His particular merit, in my opinion, consists in his treatment of mathematical physics. He has striven with great consistency to purify the mathematical theory from hypothetical assumptions which are not pure expressions of facts. In this way he has done very much to destroy the old unnatural separations between experimental and mathematical physics, and to reduce the latter to a precise and pure expression of the laws of phenomena. His electrical instruments and methods of observation, by which he has rendered, among other things, electrical phenomena as precisely measurable as magnetic or galvanic forces, gives the most striking illustration of how much can be gained for practical purposes by a close insight into theoretical questions; and his papers on thermodynamics and the experimental confirmation on several most surprising theoretical conclusions deduced from Carnot's axiom, point in the same direction."

An article in Nature, 1876, concludes with the words: "British science may be congratulated on the fact that in Sir William Thomson the most brilliant genius of the investigator is associated with the most lovable qualities of the man. His single-minded enthusiasm for the promotion of knowledge, his wealth of kindliness for younger men and fellow-workers, and his splendid modesty are among the qualities for which those who know him best admire him most."[1]

[1] The block from which the portrait of Lord Kelvin is reproduced was courteously furnished by the editors of the *Electrical World and Engineer*.—ED.

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NOTES

1. *Zi-ka-wei Magnetic Observatory.* We regret to be informed that the usefulness of the observatory work is threatened by projected electric car lines within one-half mile.

2. *Meteorological reporter of India.* *Sir John Eliot, F. R. S.*, who has filled this office with great success for many years, will retire from office at the end of the present year. *Mr. Gilbert T. Walker*, M. A., Fellow of Trinity College, Cambridge, has been appointed assistant meteorological reporter and will proceed to India during the coming summer; it is understood that he will succeed Sir John Eliot upon his retirement. Mr. Walker was senior wrangler in the mathematical tripos in 1889, took the B. S. degree in November, 1890, at the University of London, and was shortly afterwards elected Fellow of Trinity. In 1895 he was appointed lecturer in mathematical physics at Trinity. He is the author of several well-known papers on the dynamics of the boomerang. His paper on "Aberration and Some Problems connected with the Electro-magnetic Field" was awarded the Adams Prize for 1899.

Mr. Walker recently visited the following United States scientific Institutions with a view of a study of methods: Weather Bureau, Coast and Geodetic Survey, and Cheltenham Magnetic Observatory, Blue Hill Observatory, and the Yerkes Observatory.

3. *Eschenhagen's Library.* We are informed that the widow of the late lamented Eschenhagen is prepared to dispose of her husband's library. A list of books can be obtained from Mr. E. Stück, assistant, Marine Observatorium, Wilhelmshaven, Germany.

4. *Major General C. J. B. Riddle, C. B., F. R. S.* We regret to announce the death, at the advanced age of eighty-six, of this distinguished pioneer in the advancement of the sciences of terrestrial magnetism and meteorology. His "Magnetical Instructions," in many respects, have as yet deen unsurpassed. It is hoped to publish a portrait of him in a future issue.

5. *List of Observatories.* The Smithsonian Institution has recently issued (Smithsonian Miscellaneous Collections 1259) a handy alphabetical list of observatories of every description. Opposite each entry is indicated, by suitable letters, the class or classes of work each institution is engaged in.

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6. *Porto Rico Magnetic Observatory.* The United States Coast and Geodetic Survey established, under the direction of L. A. Bauer, a temporary magnetic observatory in Fort Isabel, on Vieques Island, to the east of Porto Rico. The instruments at present in operation since March 1st are, a magnetograph consisting of a Brooke unifilar and a bifilar magnetometer with Eschenhagen-Toepfer recording apparatus and a set of absolute instruments. This equipment will be supplemented by a vertical intensity variograph and a seismograph. The observatory is within two hundred and fifty miles of the Island of Martinique.

7. *Magnetic Survey of Prussia.* During 1901 Dr. Edler determined the magnetic elements at forty-four stations in the northwest part of Prussia and in 1902 at forty-nine stations in the west part. There remains the southwest portion and the repetition of observations at a certain number of repeat stations for the purpose of furnishing the necessary data for the reduction to a common epoch.

8. *Magnetically disturbed area in the Ries in Bavaria.* Prof. Haussmann investigated, in August of last year, the magnetic disturbances in this region at fifty-four stations. He hopes soon to be able to publish the results.

9. *Magnetic Survey of New Zealand.* Dr. Farr writes that the magnetic survey is making good progress. Mr. Skey attends to the field work.

10. *Professor Dr. von Neumayer.* It will certainly be a matter of regret to all readers of this JOURNAL to learn that the genial director of the Deutsche Seewarte has retired from the post which he has filled for so many years with such signal success. The title of "Excellence" has been awarded to him by the German Emperor.

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ABSTRACTS AND REVIEWS

TERRESTRIAL MAGNETISM AND ATMOSPHERIC ELECTRICITY AT THE INTERNATIONAL AERONAUTICAL CONGRESS, 1902.[1]

[Extract.]

The third meeting of the International Committee for Scientific Aeronautics appointed by the meteorologists in 1896 was held at Berlin May 20-24, 1902, the meeting having been well attended. The following extract is made from Mr. Rotch's summary of such matters pertaining to terrestrial magnetism and atmospheric electricity:

"The last session of the Congress was devoted to a discussion of measurements of atmospheric electricity and terrestrial magnetism in balloons. Assuming that the electrification of the air occurs through 'ions' or 'electrons,' as shown by the dispersion apparatus of Elster and Geitel, it is of great interest to determine how the constitution of the air, as regards positive and negative ions, varies with height. By using an aspirator to bring a definite quantity of air over the apparatus, Professor Ebert, of Munich, said that he had obtained absolute measurements of the quantity of free electricity in a cubic meter of air. In the discussion, Dr. von Bezold remarked that the connection between the Föhn wind and the number of ions in the air was now being studied. The air brought down from a great height by the Föhn carries more ions to a lower level, and there thus appeared to be a relation between mountain sickness and the well-known physiological effects of the Föhn. Professor Palazzo, of Rome, explained his photographic arrangement of Exner's electrometer, for use in balloons, and Dr. Linke, of Potsdam, described the measurements he had made in balloons to determine the change or potential and conductivity of the air. He had confirmed his early results that the potential was always positive, but found variation of the conductivity in cloud strata depends upon the weather conditions. The vertical motion of the balloon introduced complications which made the dispersion observations very difficult. On the request of Professor Ebert, the Congress recognized the importance of executing electrical measurements in balloons. The same speaker showed an apparatus for determining the horizontal magnetic intensity in a balloon without knowing either the astronomical or magnetic meridian. This is not only of scientific importance, but may be practically useful to guide the aeronaut at night and when he is in the clouds or over the sea. Dr. Marcuse, of Berlin, then showed an instrument for determining astronomically in a balloon its position. Dr. Kassner, of Berlin, suggested that kites and kite-balloons might be employed in the following scientific investigations: in physics for the determination of the conditions affecting the velocity of sound, in geodesy and astronomy for researches as to the causes

[1] Rotch, A. L. The International Aeronautical Congress, Repr. Science, Aug. 22, 1902, 6 pp.

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of the variation in atmospheric rafraction and in meteorology for a study of the action of 'hail shooting.' Finally Director Archenhold, of the Treptow Observatory, in Berlin, said that the volcanic eruptions in the West Indies may produce optical phenomena similar to those following the Krakatoa explosion, namely, first brilliant sunsets and then the luminous night clouds which would be first perceived by aeronauts during nocturnal ascensions."

CHAUVEAU'S "RECHERCHES SUR L'ELECTRICITE ATMOSPHERIQUE."

Under this title Prof. A. B. Chauveau, of the Central Meteorological Bureau, Paris, has issued recently two memoirs giving a most interesting and comprehensive report of his study of atmospheric electricity. The first memoir is devoted to an historic and bibliographic introduction to the science. Chapter I describes the various phenomena and manifestations of atmospheric electricity; Chapter II gives a historical account of the developement of the science together with a description of the apparatus and methods used; Chapter III is devoted to a statement and discussion of the various theories relative to the origin of atmospheric electricity. The author strongly favors the theories of Sohncke in holding that atmospheric electricity has its origin in the friction between the air strata immediately above and below the isothermal of 0°, and of Lenard who ascribes its origin to the action of ocean waves. As for Edlund's theory, which ascribes it to an electric field created by the rotation of the earth, it is held to be inadmissible.

In the second memoir, Part First, Chapter I describes the Mascart photographic registering apparatus; Chapter II, the methods used in measuring high potentials; Chapter III the installation of apparatus in the Central Bureau and on the Eiffel Tower. Part Second, Chapter I, is devoted to a discussion of observations made near the earth's surface; Chapter II to a discussion of the observations made at the Central Bureau; Chapter III to observations made on the Eiffel Tower; Chapter IV takes up a discussion of special observations, and investigations of special phenomena; Chapter V is given to a discussion of the results obtained at the Central Bureau and on the Eiffel Tower, and to the enunciation of the general law of the daily variations. At the end of this memoir there are a number of beautiful cuts showing the various instruments used, and many excellent reproductions of photographic curves.

L. G. SCHULTZ.

OBSERVATIONS OF THE ELECTRIC CONDUCTIVITY OF THE ATMOSPHERE AT CAPE TOWN, SOUTH AFRICA.

[Abstract][1]

Observations of the electrical conductivity of the atmosphere were carried on from May 21 to August 25, 1902, at the South African College, Cape Town, by W. H. Logeman. The original Elster and Geitel apparatus, *with protecting cylinder*, was used throughout the work. The quantity of electricity dissipated during an interval of fifteen minutes was noted for both positive and negative charges, and two sets of readings were made on each day. During May and June the conductivity was somewhat greater during

[1] From MS. communication forwarded to the Editor.

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the afternoon than during the morning: but during the morning slightly more of the positive charge was dissipated, while during the afternoon the amount of negative charge dissipated was slightly in excess. During July there was a marked difference between the morning and afternoon results, the conductivity being much greater during the afternoon; but for this month, more of the negative charge was dissipated during the morning and more of the positive during the afternoon. L. G. SCHULTZ.

ATMOSPHERIC ELECTRICITY OBSERVATIONS BY A. GOCKEL.[1]

This paper gives the results of atmospheric electrical observations made during the months of August and September, 1901, in Biscra, in the Oasis Tougourt, two hundred kilometers south of Biscra, at Hamman el Lif on the African coast, near Tunis; during March, 1902, at Zermatt and at odd times at Freiburg. The instrumental equipment consisted of an Exner electroscope, with a burning taper as a collector; Elster and Geitel's conductivity apparatus *without the protecting cylinder;* but in order to protect the apparatus against the earth's electrical field a wire cage was used; an Elster and Geitel actinometer for measu ring the ultraviolet rays; a Corva actinometer for measuring total solar radiation; a barometer and a hygrometer.

Strong winds and high temperatures interfered, to a great extent, with the observations at Biscra. The potentials were low and the values observed contradicted, in a measure, the results obtained during a previous investigation. At Tougourt sufficient data were not obtained to determine the daily period of potential variation, but they clearly show that afternoon gradients are generally higher than those of the forenoon. Here the dispersion coefficient was found to be remarkably low at sunset. While a decrease in the electrical conductivity of the air is an effect commonly observed, it is nowhere so marked as at Tougourt, and this fact accounts for the high potentials observed here during the late afternoon. No relation was discovered between the vapor pressure and the conductivity of the air; but observations at all places in the desert show that the time of minimum conductivity and maximum potential coincides with the times of minimum barometric pressure. At Hamman el Lif, on the sea shore, the conductivity was less and the potential was greater than on the desert.

During January, 1902, observations were carried out at Guggisburg in the Swiss Alps where the air is free from dust and other impurities which usually affect the electrical state at lower levels. On the two days on which observations were made, an anti-cyclonic area lay over the Central Switzerland and a Föhn wind prevailed at the place of observation. The relative humidity was low and both the conductivity and potentials were high. The formation of dense fog masses in the lower valleys and the Föhn coming from the upper air highly charged with ions caused these abnormal electrical conditions.

Observations on the Leysin Plateau, 1000 meters above the valley of the Rhone, show, nicely, the changes of the potential and conductivity of the air which occur in connection with well marked rain conditions. At Zermatt the observations show the electrical changes which accompany changes of pressure

[1] Luftelektrische Untersuchungen von ALBERT GOCKEL, Freiburg, (Schweig) 1902, Veröff. d. Un. Freiburg, Neue Folge, Fasc. IV, 56 pp., 1 pl., 17 x 25 cm.

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in mountain regions; and, in addition to observations at other mountain stations, they also bring out in a remarkable manner the effect of solar radiation upon potential changes, and throw much light upon Exner's "spring maxima." No relation was found to exist between the relative humidity and electrical state of the air. Actinometric measurements show that the Sun's rays may affect the air potentials in three ways: 1. The ultraviolet rays may exert an inductive effect upon the negatively charged surface of the earth: or 2. These rays may increase the conductivity of the air; 3. Particles which affect the transparency of the air may possess a charge of their own.

Leaving out of consideration small disturbances, all the observations seem to show that the normal daily period of potential variation consists of a single oscillation with a daytime maximum and a nighttime minimum, at places free from the influence of objects on the earth's surface; but at places where this influence is strongly felt the daily period is a double one. Of all the meteorological elements, air currents, set up by changes in temperature, are the most effective agents in causing potential variations. L. G. SCHULTZ.

STUDIES IN ATMOSPHERIC ELECTRICITY BY Y. HOMMA.[1]

[Abstract.]

The atmospheric electricity records, made at the Central Meteorological Observatory of Japan, during the year 1897, are discussed in this paper. The observatory is far enough from the city of Tokyo to be free from the effect of dust and smoke. The equipment consisted of a water-dropper collector, the end of whose nozzle was 2m from the side of the building and 1.7m from the ground, and a Kelvin-Mascart self-registering electrometer.

A cursory inspection of the traces shows that the potential varied in a most irregular and capricious manner; that there was a decided tendency toward high potentials in the cold seasons; that the morning maximum occurred, uniformly, about an hour after sunrise throughout all seasons while the evening maximum occurred anywhere from 7.00 p. m. to midnight.

After stating the various theories of atmospheric electricity, placing special stress upon the friction theory of Sohncke, and the ion theory of J. J. Thomson, as developed by Elster and Geitel, the author expresses a strong leaning toward the friction theory of Sohncke and describes several experiments which go to show how objects may become electrified by friction. Leaves, twigs, wood, etc., were placed upon an insulator and a stream of fine sand was poured upon them from an insulated vessel. The sand became negatively and the other objects positively electrified. Leaves, twigs, wood, dry ice, etc., were placed upon an insulator and a jet of steam was made to play upon them. All objects on the insulator showed negative electrification except dry ice which was positively charged. Furthermore it was found that ice was positive against all substances which were tested. A piece of lighted candle was placed upon an insulator to serve as a collector. When a gas flame was brought near it the electrometer showed a negative electrification; a stream of unignited gas, however, showed no charge. The same effect was

[1] Journal of the Coll. of Science, Imper. Univ. Tokyo, Japan; Vol. XVI.

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noted when a current of warm air was sent against the collector; but a positive charge was observed when a current of cold air was used. This experiment showed that when two masses of air, at different temperatures, are in contact the hotter one becomes positively and the cooler one negatively electrified. In order to verify this conclusion two adjoining rooms were brought to temperatures differing by about 10° and the collector was placed near the connecting door. When the door was slightly opened the flame was blown toward the warmer room and the electrometer showed an increase in potential.

The author agrees with Sohncke in holding that the layer of air just above the plane containing the isothermal of 0° and carrying ice spicules, becomes positively electrified by friction with the layer lying just below that plane and carrying water particles; and that the negative electricity of the latter partly passes down to Earth through precipitation. And, in addition, he believes that the contact of warm and cold air, the intensity of the wind and the amount of dust in the air are circumstances which play an important part in the phenomena of atmospheric electricity.

A study of the simultaneous meteorological records showed that strong winds, which raised dust, were accompanied by negative potentials; but when the ground was wet from previous precipitation the potentials remained positive although the wind blew violently. Mornings with fog or haze were generally characterized by high potentials showing energetic fluctuations.

Excessively high potentials were recorded on days with excessively low temperatures.

When rain was moderate, and the drops fine, the potential was low and positive, with only slight variations. When a violent downpour occurred the potentials became, at once, negative and showed irregular and energetic variations; as precipitation became less the potential went back to positive.

In the case of snowfall the variations were much more regular though no less energetic than with rainfall; and they seemed to show a quasiperiodic nature.

The author's conclusions are summarized as follows:

1. The negative potential observed during strong wind is entirely due to the negative electrification of the dust raised and carried in the atmosphere by friction with terrestrial objects.

2. Similarly the high potential observed during fog or haze is due to the positive electrification of the water particles composing it.

3. When a mass of cold air comes in contact with a mass of warm air, the former becomes positively electrified with respect to the latter. This fact is probably one of the causes which determine the normal distribution of the electric field in the atmosphere. Also it may account for the fact that an abnormally high potential is generally accompanied by an abnormally low temperature.

4. The invariably high potentials at or near sunrise are probably due to the fact that the air laying near the surface has then a temperature lower than that of the air above it, and becomes in consequence, positively electrified.

5. When two masses of air at different temperatures happen to be mixed suddenly, the electric field is violently disturbed. The disturbances are, however, just such as are in accord with the facts stated in 3.

L. G. SCHULTZ.

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MAGNETIC OBSERVATIONS ABOUT LAKE BALATON, HUNGARY, IN 1901.[1]

This campaign, which had for its object the revealing of possible local disturbances in the vicinity of Lake Balaton, was conducted under the auspices of the Balaton Committee of the Royal Hungarian Geographical Society, and embraced fifteen stations, at which the three elements were observed. The following instruments were used: Lamont pattern magnetometer[2] for declination and horizontal intensity, a Dover dip circle,[2] a theodolite—reading to 5″ and by estimation to 1″—by Starke for time and azimuth, two pocket chronometers by Vorauer and Courvoisier, and observing tent. Great care was exercised in the selection of stations to avoid artificial local disturbances. The method of observation and reduction was that used by I. Kurländer in the survey of Hungary, the reduction to common epoch of August 1, 1901, being made by means of the magnetograms at the Pola Observatory. The descriptions of the stations are in general not sufficiently explicit; the station Versprém is practically the same as occupied by Kurländer in 1892; without further information the impression is aroused that this station may be too close to a building.

From the remarks on the astronomical observations it is not clear why, with the instrument used, it was necessary, sighting on the sun, to make the time observations apart from the azimuth observations, and why the alt-azimuth method of observation and reduction was not at once used. The mean error of the azimuth observation would appear in general to be less than $\pm$ 0′.4, the greater part of which is due to the error of pointings on the mark before and after the solar observations, produced by the twist in the tripod by the Sun beating on it. This mean error seems to be deduced, however, simply from the separate pointings on the Sun made at practically the same hour angle, and, hence, does not include the errors, which would be revealed by observations at various hour angles, especially by A. M. and P. M. observations.

Comparisons of the magnetometer with a similar one loaned by the Vienna Meteorological and Magnetic Observatory, showed connection to Vienna standard to be — 55 γ before and — 52 γ after the trip, indicating a constant condition of instrument throughout. Summaries of intensity, declination, and dip follow. The observer does not feel that the best results were obtained with the dip circle, and in conformity with usual experience found the results especially unsatisfactory in moist conditions. After a general summary of results the author discusses a magnetic anomaly at Veszprém, his observations being confirmed by those of Kurländer. An anomaly of less prominence is also noted at Balaton-Beréney. Following a table of the X, Y, and Z components are six sketch maps showing isodynamics of horizontal intensity, isogonics, isoclinics, isodynamics of components of intensity along axis of the lake and perpendicular to it, and isodynamics of total intensity.

[1] Erdmagnetische Messungen in der Umgebung des Balatonsees. Ausgeführt im Sommer 1901, von Dr. L. STEINER, Assistent der Kön. Ung. Meteorologischen Reichsanstalt. Repr. from "Resultate der wissenschaftl. Erforschung des Balatonsees." 1 Bd., 1 Theil, III Sec. Budapest, 1902. 21x29 cm.

[2] Kurländer used the same instrument in his survey of Hungary during 1892–4.

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In Appendix I, the author discusses the advisability of making complete determinations of horizontal intensity at central stations and depending upon oscillations or deflections alone, counting upon a uniform change in m, for intermediate stations. Taking m as constant during his work and calculating values of intensity "A" from nineteen observations of oscillations with two magnets each and values "B" from a corresponding number of deflections; the mean value of $A-B$ is but 7γ indicating that the scheme of observation of deflections or oscillations alone is feasible under favorable conditions. Still for trips involving considerable transportation of instruments, the absolute method is always to be preferred.

In a second appendix are given the methods and results by G. Marczell in determining magnetic moments of samples of rock from the various stations. The weak magnetic properties of the samples made necessary that the deflected needle be held in position by a very weak field: this was accomplished by two electro-magnets north and south of the suspended needle, so reducing the Earth's field to $\frac{1}{20} - \frac{1}{50} H$. J. A. FLEMING.

U. S. C. AND G. S.

EXPERIMENTAL RESEARCHES ON DRAWN STEEL.—PART I. MAGNETISM AND ITS CHANGES WITH TEMPERATURE.—PART II. RESISTIVITY, ELASTICITY, AND DENSITY, AND THE TEMPERATURE COEFFICIENTS OF RESISTIVITY AND ELASTICITY.[1]

BY J. REGINALD ASHWORTH.

(Abstract.)

PART I.

In a former paper[2] it was shown that the variation of the intensity of magnetization of a magnet under fluctuations of temperature is controlled to a large extent by the self-demagnetizing factor of the magnet, the self-demagnetizing factor being governed by the dimension ratio. In general, an increment of temperature in the cyclic state reduces and a fall of temperature augments the magnetic intensity, so that a in the equation

$$I_{t'} = I_t \ (1 + a \ \overline{t' - t})$$

is negative, t' being a greater temperature than t and $I_{t'}$ and I_t the corresponding magnetic intensities. But it was discovered that magnets made of pianoforte wire, in the commercial state, more than 50 diameters long, exhibited a positive or incremental coefficient. If the magnet were much shorter the coefficient was decremental, and, for an intermediate dimension ratio, zero.

In the present paper a complete experimental investigation of the temperature coefficient of a magnet is undertaken. Attention is at first confined to pianoforte steel wire, and tables and curves are given of the change of a, and the change also of I, as the dimension ratio is increased from about 16 to 100 for the wire in three conditions—namely, annealed, glass hard, and commercial drawn state.

[1] Communicated to the Royal Society by PROFESSOR SCHUSTER, F. R. S., and read March 6, 1902.

[2] See *T. M.*, Vol. II, 137.

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In the first two the coefficient is decremental, and, in magnitude, large for annealed and very small for glass hard; but in the drawn state a changes from decremental to incremental as the dimension ratio advances. It thus appears that the drawing is responsible for the peculiar behavior of a.

To confirm this, experiments were made on twelve samples of pianoforte steel, representing every stage in the process of drawing from the rolled rod through annealing and tempering to the fine-drawn wire, the drawing being carried one or two steps farther than is usual in commercial practice. The experiments were made on lengths of 50 and 100 diameters. The curves which are traced show very clearly that a changes in sign at a not very advanced stage in the drawing, grows more positive, reaches a maximum, and then droops towards zero again at extreme drawing. The magnetic intensity rises steadily with drawing, and shows no tendency to diminish even at the final stage of drawing; it is then about 200 per cent greater than at the first drawing.

An examination of a piece of drawn steel wire about 400 diameters long then follows, in which susceptibility and intensity are determined when the wire was at air temperature and when it was at 100° C.

The effect of heating is very pronounced, and, unlike the general behavior of iron and steel, the hot curve of magnetization is always above the cold curve, as the steel is carried to its greatest intensity and brought to its residual condition by the withdrawal of all force. Thus it retains more magnetism hot than cold. But on demagnetizing, the hot curve droops faster than the cold curve, and the curves intersect when the reversed force is about 4 C. G. S. units, and at this point the magnetic intensity is the same hot or cold. The explanation of the fact that a self-demagnetizing force of given amount produces a zero temperature coefficient in drawn steel now becomes clear.

The influence of magnetic intensity on the magnitude of a is next investigated in a long series of observations. The wire was magnetized step by step, and at each step the temperature coefficient and the percentage permanent change of intensity were determined, both for induced and residual intensity. The temperature coefficient in general follows the susceptibility, and becomes least at the highest intensity, but always incremental; on demagnetizing it increases slightly, and then falls towards zero, which occurs at some very low residual intensity.

The behavior of the residual magnetism as demagnetization proceeds is very interesting; when a small part of the magnetism is removed, the effect of alternate heatings and coolings is to leave the intensity higher than before the application of heat and cold, and the more the magnetism is removed the greater the recovery by heating and cooling; and, at last, on applying so large a demagnetizing force as to remove all the magnetism and to leave a small residual intensity inverse to the direction of the original intensity, then heatings and coolings clear this out and restore some of the original magnetization. The behavior of the coefficient during these changes is also discussed.

For comparison, the same series of experiments was performed upon an annealed iron wire about 400 diameters long. The hot curve of magnetization crosses the cold curve a little beyond maximum susceptibility, and the maxi-

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mum residual intensity is less hot than cold; it would, therefore, appear that at some small initial intensity the coefficient should be positive, at a later stage zero, and, finally, negative. The zero coefficient was not obtained in these experiments, but the subsequent negative coefficient was traced, and it was found that when the susceptibility is large the negative coefficient is a minimum; the coefficient is throughout negative during demagnetization.

The intensity under heating and cooling is similar in behavior to the intensity of drawn steel; on magnetizing, heatings and coolings always cause a loss of residual magnetism, but on demagnetizing, heatings and coolings restore some of the magnetism removed. It would no doubt be advantageous for the sake of producing a magnet of constant intensity to apply a small reversed force after magnetizing to saturation; any fluctuations of temperature afterwards would then tend to increase rather than diminish the intsensity.

It is pointed out that the gradual decay of magnetism in observatory magnets will generally be accompanied by some change in the coefficient, and that remagnetization of magnets will likewise alter the magnitude of the coefficient; the general effect of this change will be determined by the position of the point of intersection of the hot and cold curves of magnetization.

Observations, extending over several years, then follow on four magnets made of drawn steel and treated in two different ways so as to have nearly zero coefficients, and the effects of time and the effects of remagnetization on the temperature coefficient and on the intensity are studied.

PART II.

The series of wires representing the twelve stages in the manufacture of drawn wire were subjected to examination for resistivity and its temperature coefficient, for Young's modulus and its temperature coefficient, and for density.

Resistivity is augmented by tempering but diminished by drawing up to a certain stage; extreme traction, however, causes a rapid increase again of resistivity.

The temperature coefficient is related to the resistivity, so that, in general, high resistivity and low coefficient are associated. Drawing, however, does not produce a very large change in the temperature coefficient of resistivity.

Young's modulus increases markedly with tempering and to a less extent with drawing up to the point where the resistivity is a minimum; after that, extreme drawing produces a sharp diminution of the modulus.

The temperature coefficient of Young's modulus presents an interesting relation to the modulus and like the resistivity coefficient follows in an inverse sense the modulus curve, so that when the modulus is large the coefficient is small.

It was observed that after heating and cooling the wire the value of Young's modulus did not return to its initial value, but was always a little greater; perhaps this was not a permanent effect, although it persisted for some time.

A careful series of determinations on the density of the wires showed that, with some initial irregularities, the density is very decidedly increased by drawing to the very last stage, when it becomes 8 grammes per c. cm.

There is a very close correspondence between density and magnetic

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intensity, the two being nearly proportional to one another over a considerable range; there is also some evidence of agreement between a smooth curve of Young's modulus and the magnetic intensity; both appear to be functions of the density.

MAGNETIC OBSERVATIONS AT POLA OBSERVATORY IN 1901.[1]

This publication presents in a very complete and interesting form the results obtained from the magnetograph records of the year. The equipment comprised a unifilar, a bifilar, and a balance, which were in continuous operation throughout the year except on three occasions when the records were interrupted for about a day each time owing to the light going out or becoming defective. For the first seventeen days in January the results from the unifilar are unreliable owing to the formation of a hairlike fungus growth in the magnet house, due to the unavoidable dampness of the underground observatory. The same thing occurred in July, 1902, at the Baldwin Magnetic Observatory of the U. S. Coast and Geodetic Survey, where the instruments (Eschenhagen pattern) are mounted in an extemporized structure partly underground.

There are given in full the monthly tabulations of the hourly values of declination, horizontal intensity and vertical intensity also the daily, hourly, and monthly means, daily maximum and minimum values, and daily range. The character of the curve, a. m. and p. m., is indicated by numbers corresponding to the degree of disturbance. The monthly means are as follows:

1901	*D*	*H*	*Z*	1901	*D*	*H*	*Z*	1901	*D*	*H*	*Z*
	° ′	γ	γ		° ′	γ	γ		° ′	γ	γ
Jan.	9 22.68	22217.7	38874.5	May	9 20.50	22229.5	38843.0	Sept.	9 19.78	22236.4	38852.4
Feb.	22.08	15.1	61.0	June	19.91	33.3	48.0	Oct.	18.87	31.3	36.8
Mar.	21.48	20.2	46.5	July	19.76	47.1	65.3	Nov.	18.26	32.0	27.1
Apr.	21.12	22.9	37.7	Aug.	19.37	43.4	55.7	Dec.	17.91	32.1	27.6

And the mean daily range:

1901	*D*	*H*	*Z*	1901	*D*	*H*	*Z*	1901	*D*	*H*	*Z*
	′	γ	γ		′	γ	γ		′	γ	γ
Jan.	2.87	21.8	16.5	May	9.44	28.6	25.9	Sept.	8.04	33.8	22.8
Feb.	4.92	26.4	12.0	June	9.33	31.8	25.3	Oct.	7.07	24.2	19.0
Mar.	7.74	24.9	21.3	July	8.56	31.3	25.1	Nov.	4.42	22.6	12.5
Apr.	9.64	26.1	28.8	Aug.	8.68	34.9	19.8	Dec.	3.49	21.6	13.3

[1] Jahrbuch der Meteorologischen, Erdmagnetischen und Seismischen Beobachtungen, Neue Folge, VI. Band. Veröffentlichungen des Hydrographischen Amtes der Kaiserlichen und Königlichen Kriegs-Marine in Polo.

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Other tables give the means of the hourly differences from the monthly mean for declination, horizontal intensity, vertical intensity, inclination, total intensity and X and Y components. Still other tables give the number of disturbed hourly values and their distribution over the day.

The absolute observations were made at varying intervals averaging seven days apart for declination, twelve days for horizontal intensity, and six days for inclination. The results are given in tabular form. The values of the D, H, and Z base lines for each day of the year are also tabulated.

In an appendix there are curves showing how the daily ranges are affected by the seasons. There are also curves showing the distribution of disturbances over the day.

By comparing the monthly means from 1890 to 1901, the *following values of the annual change for the period 1899-1901 are derived:*

Declination (decrease in W. decl'n)	−4.′9	W. component	−26γ
		Inclination	−1.′8
Hor. intensity	+31γ	Vert. intensity	+13γ
N. component	+36γ	Total intensity	+28γ

In December, 1899, an iron roof was put on a building situated about thirty-five paces from the observatory. Special absolute observations were made to determine the effect on the magnetic elements. It was found that it required three months for the magnetic field to reach a stable condition.

The records of the year do not reveal any notable abnormal manifestations.

WM. F. WALLIS.

BALDWIN, KANSAS.

PHOTOGRAPHIC EFFECTS OF BECQUEREL RAYS IN THE ATMOSPHERE.

A concise account of work done in common with Prof. H. Geitel in showing the photographic and other effects of the radioactivity imparted to negatively charged conductors by contact with the atmosphere. Copper wires ten meters long suspended in the open are kept negatively charged to a few thousand volts for several hours. The wire is then taken in and rubbed briskly with a piece of leather dampened with ammonia water, this process transferring the radioactivity from the wire to the leather, which may be quickly dried over a flame without loss of activity. With the lapse of time the activity decreases rather rapidly, so that after twelve hours only a small fraction of the original activity remains. With five successive exposures of four hours each to pieces of leather made radioactive in this way, radiographs of a lead stencil were obtained on a photographic plate through aluminum foil 1-10 mm. thick. Leather can indeed be made so strongly active as to cause visible action on a fluorescent screen. It is pointed out that since the whole surface of the Earth is negatively charged with reference to the atmosphere, it is doubtless radioactive and continuously ionizing the surface layer of air.

G. B. PEGRAM.

[1] ELSTER, J. Ueber die Herstellung von photographischen Eindrücken durch Becquerelstrahlen, die der atmosphärischen Luft entstammen. Repr. from "Jahrbuch für Photographie und Reproductionstechnik, für das Jahr 1902." 7 pp. 12 x 19 cm.

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RECENT PUBLICATIONS

BARACCHI, PIETRO. Results of observations in meteorology and terrestrial magnetism made at the Melbourne Observatory, and other localities in the State of Victoria, Australia, July 1,–Dec. 31, 1901. Melbourne, 1902. 52 pp., 15½ x 24½ cm.

Contains following magnetic results:

Date. 1901.	Melb. M. T.	Decl'n. E.	Melb. M. T.	Incl'n. S.	Melb. M. T.	Hor. I.	Vert. I.	Total I. (c. g. s. units.)
	h m	° ′	h m	° ′	h m			
Sept. 20	12 22*p*	8 26.68	4 05*p*	67 24.98	11 05	.23305	.56024	.60679
" 23	.....	.....	3 17*p*	26.83	.....	.....	.....	.....

BELGIQUE, OBSERVATOIRE ROYAL DE. Annuaire Météorologique pour 1903 publié par le soins de *A. Lancaster*, Directeur du Service météorologique. Bruxelles, 1903. Pp. 662, 10 x 14 cm. [Pp. 408–409, annual values of the magnetic elements at Uccle, 1895–1902.]

CREAK, E. W. Elementary Manual for the Deviations of the Compass in Iron Ships. J. D. Potter, London, 1903. Pp. 150, and 4 charts. 16 x 24 cm.

CORTIE, A. L. Minimum sun-spots and terrestrial magnetism. Repr. Astrophys. J., vol. XVI, 1902, pp. 203–210.

DUKE OF THE ABRUZZI. Osservazioni scientifiche eseguite durante la spedizione polare di S. A. R. Luigi Amedeo di Savoia Duca degli Abruzzi 1899–1900. Ulrico Hoepli, Milan, 1903. Large 8°, 724 pp. [This sumptuous volume contains the scientific results of the polar expedition, 1899–1900. The two chapters of interest to magneticians are: Pp. 195–207, Aurore boreali; and pp. 435–501, Osservazioni magnetiche. Reviews of these will appear later.]

MACKENZIE, A. STANLEY. An instrument for drawing a sine curve. Phys. Rev. Dec., 1902, p. 366.

POTSDAM MAGNETISCHES OBSERVATORIUM. Ergebnisse der magnetischen Beobachtungen in Potsdam im Yahre 1900. Veröffentlichungen d. K. Preuss. Meteorol. Inst., (W. von Bezold, Director) 1900. Heft. 2. Berlin, 1902. 44 pp. and 4 pl. 25 x 33 cm. [Contains the usual hourly tabulations of the magnetic elements, their variations and perturbations, and 4 plates of diagrams.]

RED SEA MAGNETIC OBSERVATIONS. Magnetische beobachtungen; expedition S. M. schiff "Pola" in das Rothe meer (September 1897–Marz 1898). (*C. Rössler*) Commission für oceanographische forschungen: Berichte 7, 221 (1901).

SCHUSTER, ARTHUR. The solar atmosphere. Repr. Astrophs. J., vol. XVI, 1902, pp. 320–327.

ROTCH, A. L. The circulation of the atmosphere in the tropical and equatorial regions. Repr. Monthly Weather Review, April, 1902. 44 pp. and 2 figs. 14½ x 23 cm.

TOKYO. Publications of the Earthquake Investigation Committee in Foreign Languages. Nos. 7 and 11. 1902. [Contents of No. 7: *A. Tanakadate*, vertical motion seismometer; *A. Imamura*, seismic triangulation in Tokyo; *A. Imamura*, a mechanical starter; *F. Omori*, note on the aftershocks of the Mino–Owari earthquake of Oct. 28, 1901; appendix, list of earthquakes observed at Nemuro. Contents of No. 11: *F. Omori*, macro-seismic measurement in Tokyo. II and III.]

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J. J. Thomson

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Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME VIII JUNE, 1903 NUMBER 2

THE CAUSE OF THE EARTH'S MAGNETISM.

By William Sutherland.

In this Journal for June, 1900, it was shown that a sphere of radius a charged with electricity of volume density ρ, and revolving round an axis with angular velocity Ω, would have a magnetic potential at a point r, θ where θ is the colatitude,

$$\int_o^a \frac{4}{3}\pi\Omega\cos\theta\,\rho\,R^4\,dR/r^2. \qquad (1)$$

If an equal amount of the opposite sort of electricity were distributed through a sphere of radius $a - da$, its volume density ρ' would be determined by the condition,

$$\rho'(a-da)^3 = \rho a^3;\ \text{hence, } \rho' = \rho(1+3\,da/a), \qquad (2)$$

and its magnetic potential would be,

$$\int_o^{a-da} \frac{4}{3}\pi\Omega\cos\theta\,\rho(1+3\,da/a)R^4\,dR/r^2.$$

The magnetic potential of the two distributions together would be

$$\frac{4}{3}\pi\Omega\frac{\cos\theta}{r^2}\left\{\rho_a\,a^4\,da - \frac{3\,da}{a}\int_o^a \rho\,R^4\,dR\right\}.$$

If ρ is assumed to be not a function of R, this becomes

$$\frac{8}{15}\pi\Omega\,\frac{\cos\theta}{r^2}\,\rho\,a^4\,da. \qquad (3)$$

This is the right form of expression for the average magnetic potential round parallels of latitude on the Earth's surface.

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As to the two distributions of electricity throughout the substance of the Earth, we have now strong evidence. In Helmholtz's theory of chemical valence of the atoms, each bond between the atoms in a molecule is supposed to consist of two opposite electrons associated with the atoms. For convenience I have proposed (*Phil. Mag.*, Feb., 1902) to denote the positive electron by ♯ and the negative by ♭. With the aid of this notation, Helmholtz's theory can be summarized by writing the chemical formula for *NaCl* in the form *Na*♯♭*Cl*, in which *Na*♯ and ♭*Cl* are the two ions into which *NaCl* is resolvable. I have sought to show (*Phil. Mag.*, Dec., 1902) that all the phenomena of cohesion can be traced to these electric doublets ♯♭ in molecules, for they act as the electric analogues of minute magnets.

Thus, then, every ordinary molecule involves in its own existence that of at least one ♯ and one ♭. The whole Earth, then, contains two opposite enormous charges of electricity. These charges are so nearly equally distributed throughout the Earth that they produce no external electrical effect; they help to hold the atoms together in chemical combination, and they cause the cohesion of the Earth's material with the assistance of gravitation. If the two charges of electricity were distributed through the Earth in absolute equality, their magnetic fields would exactly neutralize one another, and we should have no terrestrial magnetism. It is of importance therefore to inquire what difference in the distributions of the Earth's two charges of electricity would be required to account for its magnetic field. With this end in view the opposite charges were supposed above to be distributed through spheres of radii a and $a-da$. For the average magnetic potential Ψ, in electro-magnetic units, round a parallel of latitude $\pi/2 - \theta$, in 1880 von Bezold has given

$$\Psi = .330\, a \cos\theta.$$

Accordingly we have from (3) with $r = a$ at the surface of the Earth, and with c for the velocity of light

$$\frac{8}{15}\pi\,\Omega\,\rho\,a\,da = .330\,c. \qquad (4)$$

Now we can determine the order of magnitude of ρ by the following argument. Each molecule of the Earth contains at least one ♭, the amount of whose charge is usually denoted by e. We may take the average molecular weight of the Earth's substance to

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be in round numbers 100, so that, if h is the actual mass of an atom of hydrogen, the mass of the average molecule in the Earth is $100\,h$. But the whole mass of the Earth is $4\,\pi\,D\,a^3/3$, where D is its mean density, so the total number of molecules in the Earth is $4\,\pi\,D\,a^3/300\,h$, and therefore the total charge of negative electricity in the Earth is $4\,\pi\,D\,a^3\,e/300\,h$, and its density ρ is $De/100\,h$. But e/h is a fundamental electrical constant having the value $10^{17}/345$, and

$$a = 637 \times 10^6\ cm.,\ \Omega = 2\pi/24 \times 60 \times 60,\ D = 5.7,\ \text{and}\ c = 3 \times 10^{10}.$$

These values in (4) furnish the value 8×10^{-9} for da. But the order of magnitude for the diameter of ordinary molecules is about $10^{-8}\ cm$, and (*Phil. Mag.*, Dec., 1902) this seems to be about the distance between ♯ and ♭ in a binary molecule. Thus we have found that if the negative and the positive electricity in the Earth are spread over concentric spheres whose radii differ by only the diameter of a single molecule, they can account for the Earth's primary magnetic field. This separation of the two electricities would produce no external electric effect. It implies a minute tendency of each ♭ of a molecular doublet to turn farther from the center of the Earth than ♯ does.

In my paper of June, 1900, above cited, a cosmical separation of large charges of the two electricities in the interior of the Earth was treated as a possible cause of its magnetism. Now I would propose that an inequality in the distribution of its atomic charges, such as has just been considered, is a much more probable cause. We know that the Earth does contain two enormous opposite charges of electricity, which are almost certainly in rotation with it. It remains now only to prove that there must be such an inequality in the distributions of the two charges as we have briefly investigated, in order to demonstrate that the atomic electric charges are the true source of the Earth's magnetism. Helmholtz suggested that to account for the contact difference of electric potential in metals, we must suppose atoms to exert different attractions on the two sorts of electron. Many physicists see in the cathode rays evidence that the metals attract negative electricity less than positive. J. J. Thomson has pointed out (*Phil. Mag.*, [5] xxxvii, p. 358) that if there is this difference of attraction for the two electricities in the atom, then a large rotating body should generate a magnetic field. Kelvin and other physicists have suggested that magnetism may be a property of rotating masses,

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which becomes measurable only when the masses are large enough. From our equation (3) we can estimate what ought to be the magnetic field of any heavenly body of which we know the radius a, the angular velocity of rotation Ω, and also the density D, with which to estimate the electric density ρ as we have done above. Until we know more, it will be simplest to assume either that da is the same for all heavenly bodies, or is proportional to their masses.

On the present theory magnetism must be a property of all rotating bodies. It is the comparatively minute outstanding difference between the two opposite magnetic fields generated by the opposite electricities associated with matter. In this aspect it reminds one of surface-tension, which reveals the play of molecular forces that escape ordinary observation.

With the aid of equation (3) it is possible to show that the effects of the Sun's magnetic field on the Earth are beyond our existing means of detection. The Sun's effect on terrestrial magnetism must be indirect, as is the prevailing opinion. Concerning the Sun's magnetism, special importance attaches to Bigelow's location of the solar magnetic poles by means of the polar rays of the corona shown in eclipse photographs and drawings. The solar magnetic poles, like the terrestrial, do not lie in the axis of rotation, nor do they lie on a diameter. The repetition of the magnetic asymmetry of the Earth in the solar magnetic field is an important fact in planetary magnetism.

To carry the present theory of stellar magnetism farther, the main desiderata are (1) a demonstration of the difference in the attraction of matter for the two sorts of electricity, and (2) determination of the law of attraction between matter and electricity, to ascertain whether it is such as to cause negative electrons in molecules to take up a position which on the average is farther from the center of the Earth than that taken by positive electrons.

Melbourne, June, 1903.

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AN ANALYSIS OF THE RESULTS FROM THE KEW MAGNETOGRAPHS ON QUIET DAYS DURING THE ELEVEN YEARS 1890–1900, WITH A DISCUSSION OF CERTAIN PHENOMENA IN THE ABSOLUTE OBSERVATIONS.[1]

By Charles Chree, Sc. D., LL. D., F. R. S., Superintendent of the Observatory Derartment.

[Author's Abstract.]

The late Kew Observatory Committee joined in 1890 in a scheme whereby five days each month were to be selected as magnetically *quiet* days by the Astronomer Royal, with a view to the curves on these days being tabulated by observatories which did not care to undertake the tabulation of every day's curves. That scheme has been persisted in, and the present paper deals with the results it has led to during the eleven years 1890–1900. The paper treats of the secular change in the several elements, of the annual inequality, of the diurnal inequality, and the non-cyclic effect in the diurnal variation. Attention is more particularly given to the declination, inclination, and the horizontal and vertical components, but some consideration is also given to the northerly and westerly components of the horizontal force and to the total force.

Diurnal inequalities are got out for each month of the year in the principal elements. These inequalities are analysed into Fourier's series, and the variation of the Fourier co-efficients is traced throughout the year. Attention is also given to the variation throughout the year in the ranges of the diurnal inequalitiies and in the sum of the twenty-four hourly differences from the mean for the day. The diurnal inequalities are shown graphically in various ways, serving to illustrate different features.

As explained in a "Preliminary Note," the relation between magnetic phenomena and sun-spot frequencies have been investigated. The present paper treats of this investigation in detail. Attention is given to the ranges, and the sum of the twenty-four hourly differences from the mean of the day in the diurnal inequalities, and to the amplitudes and phase angles of the terms in the Fourier series representing these inequalities. Some of the results obtained for Kew are compared with corresponding results for Wilhelmshaven and Parc St. Maur, based on data given by Börgen and Moureaux. The results from the stations compared showed a very good agreement.

It is found that the non-cyclic effect in the diurnal variation, and the

[1] Received May 1, and read May 28, 1903, before the Royal Society.

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variability in the declination—recently discussed by the author in connection with the observations of the "Southern Cross" Antarctic Expedition—show a relation to sun-spot frequency similar to that observed in the ranges of the diurnal inequalities themselves.

A comparison is made between magnetic and meteorological phenomena at Kew from two groups of years, the one representing large, the other small sun-spot frequency. This serves to bring out the insignificance of the connection between meteorological phenomena at a given station and sun-spots—if any such connection exists—as compared to the connection between magnetic phenomena and sun-spots.

A comparison is instituted *inter alia* between the variation throughout the year in the amplitude of the Fourier co-efficients in the series found for diurnal inequalities of the magnetic elements and atmospheric temperature, making use of the temperature data discussed by General Strachey. It is shown that the amplitudes of the twenty-four hour term in the Fourier series in the two cases vary in a very similar fashion throughout the year, but that this is not true of the twelve-hour, eight-hour, or six-hour terms. Attention is also called to the fact that, in the temperature diurnal inequality, the twenty-four-hour term preponderates in a way that is not found in any of the magnetic elements. The bearing of this is pointed out on theories as to the source of the magnetic diurnal inequality.

Attention is also drawn to the peculiarity in the variation from month to month in sun-spot frequencies, which enables a somewhat searching inquiry to be made as to the simultaneity of changes in sun-spot frequency and magnetic ranges.

A final section deals with the true nature of the connection between sun-spot frequency and magnetic phenomena. A comparison is made between Wolfer's provisional sun-spot frequencies for all days in the year and for the Astronomer Royal's magnetically quiet days. The conclusion come to is that sun-spot frequency on any particular day is no guide to the magnetically quiet or disturbed character of the day, and that even mean results for a month for sun-spot frequency and magnetic ranges are but slightly related. It is pointed out that the phenomena observed would be consistent with the view that increased sun-spot activity and increased magnetic activity on the earth are due to some common source external to the sun, whose effect at the same instant varies appreciably throughout the solar system. If the source lies in the sun itself, it is concluded either that sun-spots afford no satisfactory quantitative measurement of it, or else that the effect at the earth is influenced by what takes place at the sun during a considerable time. If the source of the magnetic diurnal inequality be, as has been suggested by various physicists, electrical currents generated by the sun's action in the upper atmosphere, the cause of the increase in the amplitude of the inequality at

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times of great sun-spot frequency may be some form of radiation which reduces the resistance of the atmosphere to currents generated by the sun. This would explain the phenomena without requiring the enormous variations in the sun's output of energy from year to year that would appear necessary to account for the great variations in the magnetic phenomena, variations moreover which—as the paper shows—do not appear to be accompanied by any but the most insignificant changes in the amplitude of the temperature inequality at the earth's surface. The importance is pointed out of reliable information as to whether atmospheric electricity potential, at low and at high levels, resembles magnetic phenomena in being largely different in years of large and small sun-spot frequency.

NATIONAL PHYSICAL LABORATORY.

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ADOLF SCHMIDT'S CHARTS OF THE EARTH'S MAGNETIC COMPONENTS FOR 1885.[1]

The usual iso-magnetic charts give the lines of equal magnetic declination, of equal magnetic inclination, of equal horizontal intensity, or of equal total intensity. Schmidt makes a welcome addition to this customary list by contributing the charts giving the lines of equal northerly components (X), equal easterly components (Y), and of equal vertical components (Z) as based upon the computed quantities resulting from his harmonic analysis of the Earth's magnetic field for 1885; these computed quantities of X, Y, and Z for every 5° in latitude and longitude are published in "Aus dem Archiv der Deutschen Seewarte," 1898.

A superficial glance at the accompanying figures show that the *general* appearance of the chart of the X component (the magnetic force component directed due north or south) is that of the horizontal intensity chart, whereas that of the Y component (the force component directed due east or west) resembles in a general way the isogonic chart and that of the Z component (the force component directed vertically downwards or upwards) the isoclinic chart; a more minute examination will, however, reveal striking departures.

Both X and Y vanish at the magnetic poles, the positions of which as determined by Schmidt's analysis are: Magnetic North Pole: Latitude, 71° 10′ N., Longitude, 95° 38′ West of Greenwich; Magnetic South Pole: Latitude, 75° 39′ S., Longitude, 148° 27′ East of Greenwich.

At the *geographical* poles we have, as expressed in c. g. s. units:

North Pole	South Pole
$H = 0.04978$,	$H = 0.10008$
$X = 0.04978 \cos (\lambda - 58° 47')$,	$X = 0.10008 \cos (-\lambda + 334° 38')$
$Y = 0.04978 \sin (\lambda - 58° 47')$,	$Y = 0.10008 \sin (-\lambda + 334° 38')$
$Z = 0.57860$,	$Z = -0.62651$

The maximum values of the northerly component X are 0·385 (in the Gulf of Siam) and 0.360 (vicinity of Galapagos Islands), the maximum easterly component Y is 0.087 in the northern hemisphere and 0.106 in the southern, whereas the minimum easterly component (i. e., maximum westerly component since Schmidt regards Y positive eastward) is 0.091 in the northern hemisphere and 0.107 in the southern. The maximum vertical component is 0.634 (northern hemisphere) and the minimum —0.674 (southern hemisphere).

The scale of the maps in figures 1, 2, and 3 is for the equator 1/200000000 and at latitude 60°, 1/100000000, whereas the scale for figure 4 is 1/100000000.

[1] Bemerkungen zur Karte der Linien gleicher Werte der erdmagnetischen Komponenten von DR. AD. SCHMIDT, Repr. Petermann's Geogr. Mitteilungen, 1898, Heft VII. 5 pp. and chart.

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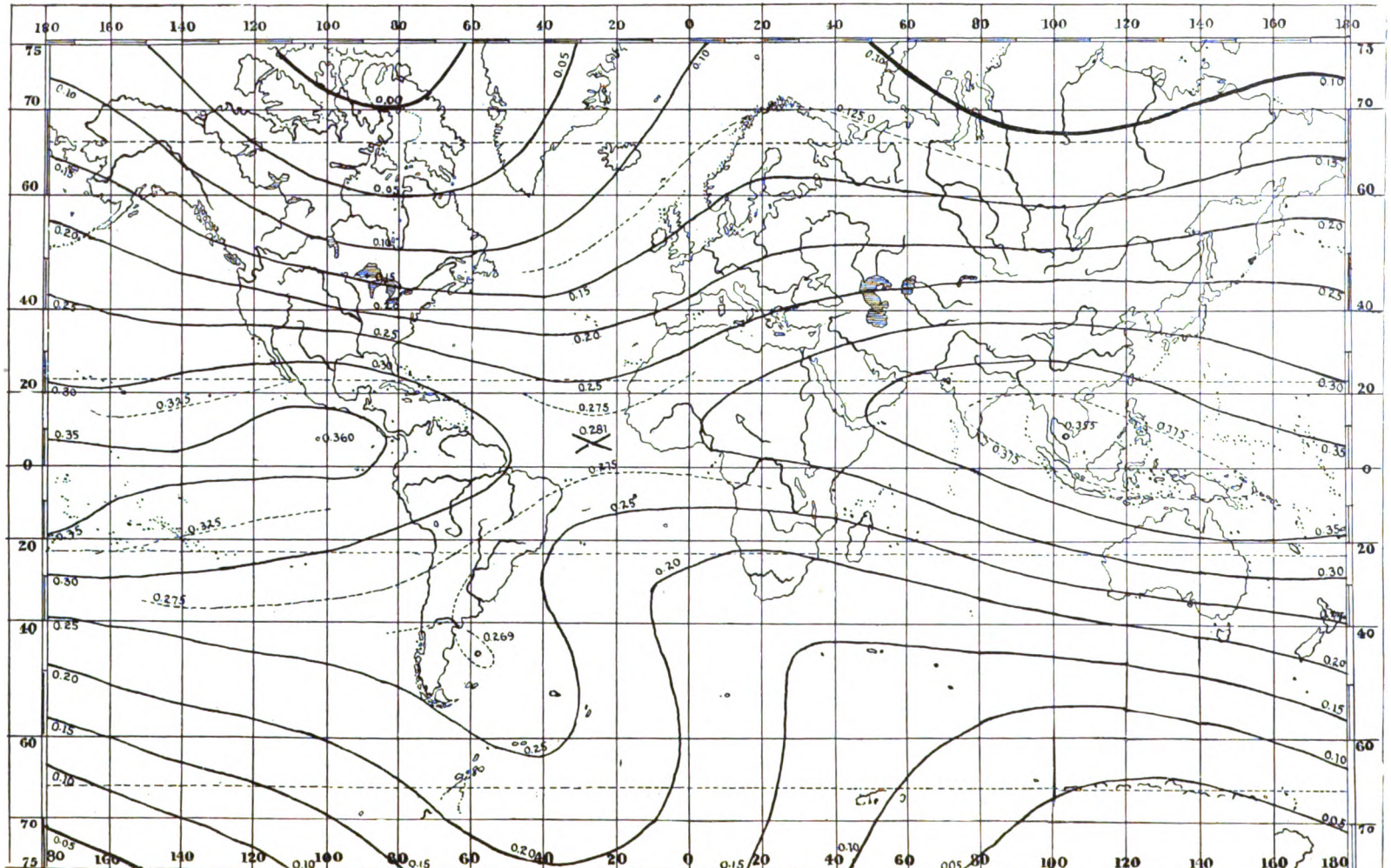

FIGURE 1. Chart of Northerly Component (X) for 1885.

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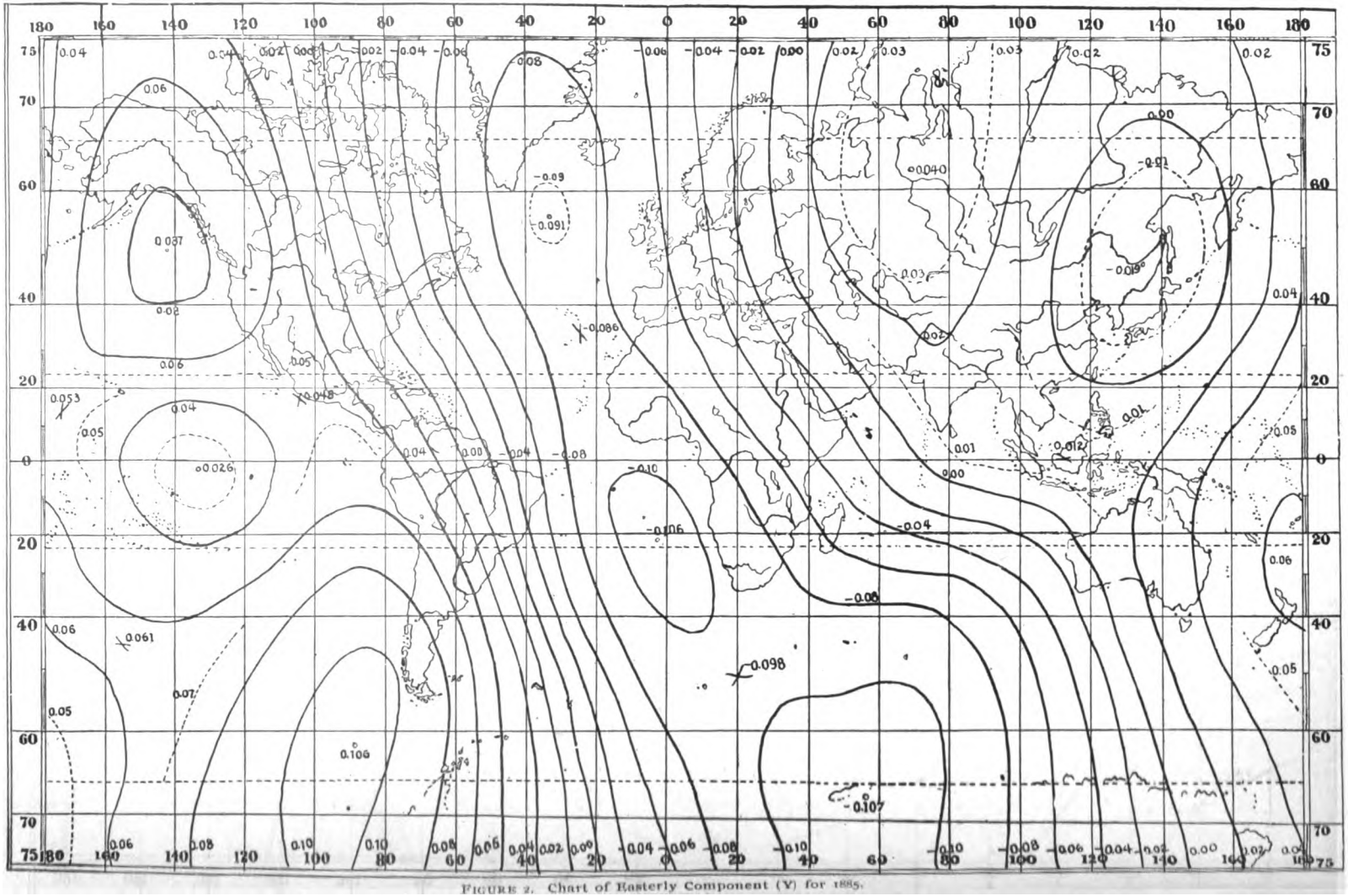

FIGURE 2. Chart of Easterly Component (Y) for 1885.

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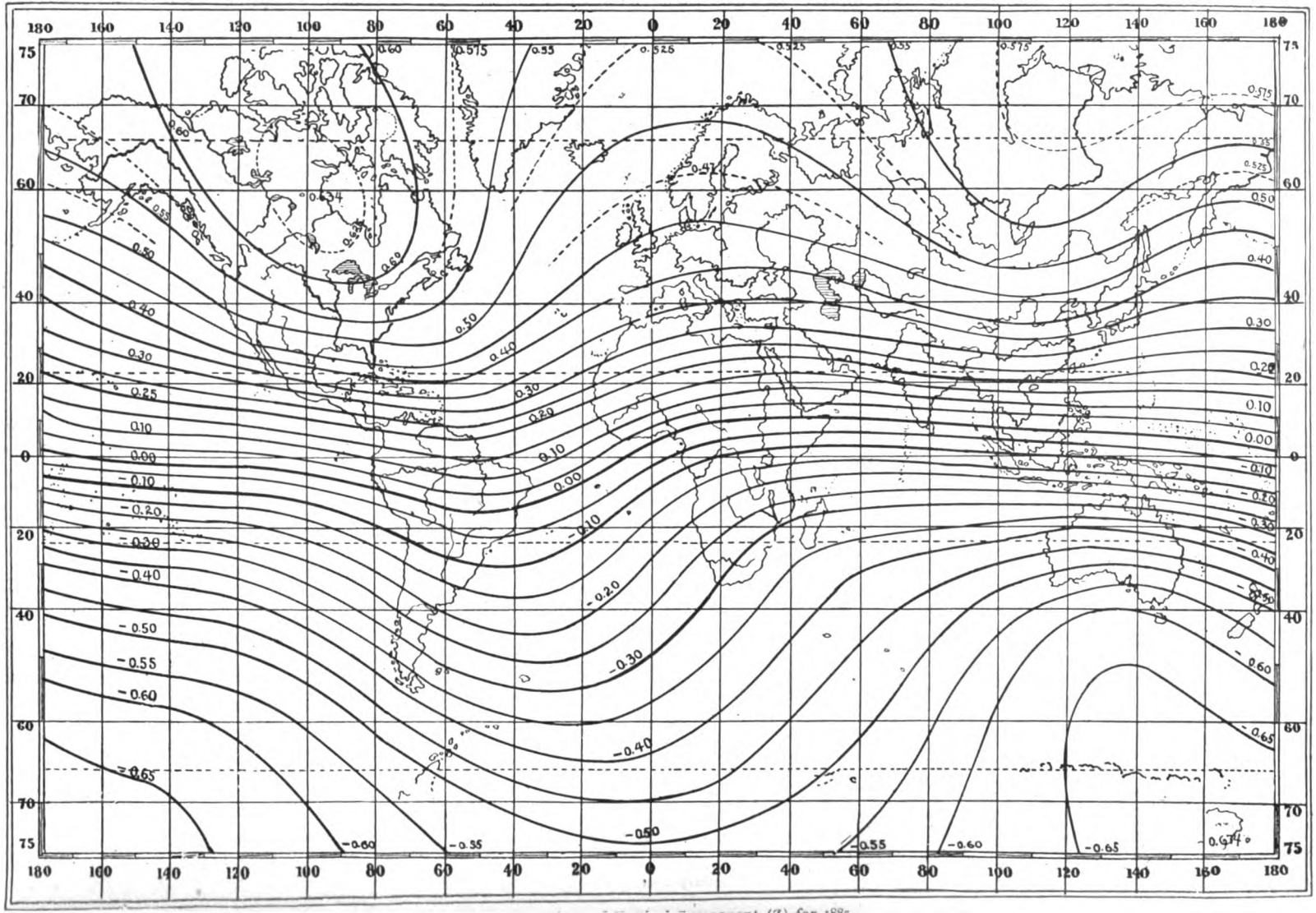

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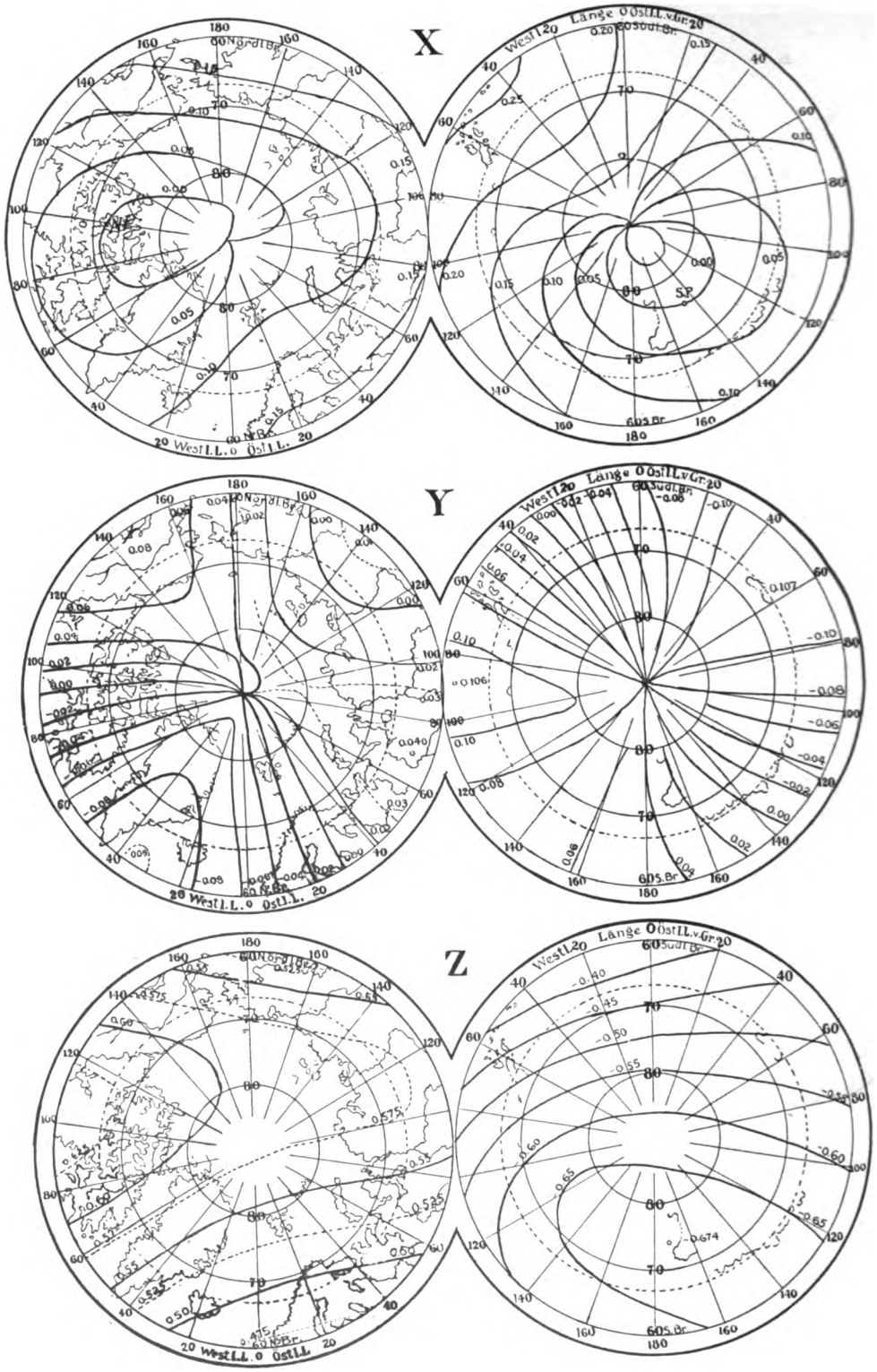

FIGURE 4. The Components in the Polar Regions for 1885.

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RESULTS OF THE MAGNETIC OBSERVATIONS IN THE UNITED STATES UP TO JUNE 30, 1902.

By L. A. Bauer and D. L. Hazard.

Two recently issued publications bring the results of the magnetic (declination, dip, and intensity) in the United States up to the date, June 30, 1902.

The "Magnetic Declination Tables for 1902," cited in the foot-note below,[1] is a continuation of the series of papers begun in 1855, treating of the magnetic declination in the United States, the last one published having been by the late Mr. Schott in the year 1897 and giving the results for 1900. The form of publication has been altered into the more convenient octavo form.

To meet the demand for general information regarding the Earth's magnetic phenomena, the present tables have been prefaced by a historical and descriptive summary, accompanied by numerous and pertinent illustrations of the principal facts of the Earth's magnetism.[2] The principal topics treated under this head are: Early history of the compass, birth of the science of terrestrial magnetism, the Earth, a great magnet, the variations of the Earth's magnetism, magnetic observatories, magnetic charts, magnetic surveys, and the Earth's magnetic poles and magnetic moment.

A chapter has been added giving briefly methods for determining meridian lines and the magnetic declination, and in another are set forth the facts concerning the secular change of the magnetic declination in the United States and outlying territories, accompanied by the necessary tables of the amount of change for various periods.

The accompanying Chart of the "Lines of Equal Magnetic Declination in the United States" contains, in addition, the "Lines of Equal Annual Change," thus adding greatly to the convenience in the practical utilization of the Chart. With their aid the corrections to the "Lines of Equal Magnetic Declination" for any subsequent year prior to the next edition can readily be made. The Chart, as stated in its legend, is based on all known observations up to date, and refers to January 1, 1902. The base map contains sufficient physical features and names of towns to render it possible to locate readily on the map any desired place. An isogonic chart of Alaska is also given.

The "Magnetic Declination Tables," forming the main body of the publication, contain about 8,000 entries, and are the most complete tabular presentation of declination values in the United States.

[1] United States Magnetic Declination Tables and Isogonic Charts for 1902, and Principal Facts relating to the Earth's Magnetism by L. A. Bauer, Chief of Division of Terrestrial Magnetism. Separate Publication of the United States Coast and Geodetic Survey, *O. H. Tittmann*, Superintendent, Washington, 1902. 406 pp. 20 x 29 cm. 29 figs. in thetext and 3 plates.

[2] How general the demand for such information has been may be judged from the fact that the entire edition of four thousand copies of this publication has already been exhausted, and a second edition is now in the press.—Ed.

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"Descriptions of the Coast and Geodetic Survey Magnetic Stations occupied between 1881 and June 30, 1902," conclude the publication. The descriptions of the stations previous to 1881 are contained in Appendix 9, Report for 1881.

The second publication[1] contains the results of dip and intensity observations between January, 1897, and June 30, 1902; those made prior to January, 1897, are contained in previous publications of the Coast and Geodetic Survey. The reduction to a common epoch is deferred pending the accumulation of additional secular variation data.

The publication of this paper and of the "Magnetic Declination Tables" alluded to above, mark, in a certain sense, the close of the initial period of the detailed and systematic magnetic survey of the United States and countries under its jurisdiction, which was inaugurated on May 1, 1899. During this period, from May 1, 1899, to June 30, 1902, a little over three years, all the instruments (16 dip instruments and 15 magnetometers), have been overhauled, modified, and improved whenever needed, and intercompared; four[2] magnetic observatories have been established and the instruments with which they are equipped have been carefully examined, tested, and put in operation. Field instruments of nearly every pattern now on the market (English, French, German, and Russian), have been purchased, critically studied, tested and compared, and a variety of investigations relating to instrumental constants, standardizations, and methods of observation have been made. Twenty persons have been trained in magnetic work, and, in addition to special field investigations, the magnetic elements have been determined at about 800 stations (about one-fifth of the total number proposed for the general magnetic survey) and the results have been prepared for publication.

The completion of this arduous initial work makes it possible to continue the magnetic survey (land and coast waters) and observatory work with unexcelled facilities and instrumental equipment. With this indication of future field activity, effort will be made to keep the office computations and reductions up with the observational work, as nearly as that is possible, so as to insure prompt publication of the results. The results obtained during any one fiscal year will hereafter be published in the Superintendent's report for that year.

In the present tables, the dip and intensity results were referred to standard instruments whenever possible. Some idea of the magnitude of these corrections will be obtained from the following exhibits:

[1] Results of magnetic dip and intensity observations made by the United States Coast and Geodetic Survey between January, 1897, and June 30, 1902, by DANIEL L. HAZARD, Computer, Division of Terrestrial Magnetism, with preface by L. A. BAUER, Inspector of Magnetic Work and Chief of Division of Terrestrial Magnetism. Appendix 6, Report of Superintendent *O. H. Tittmann* for 1902. Pp. 335, 336. Also published as a separate.

[2] A fifth was established in February, 1903, on Vieques Island, Porto Rico.—ED.

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CORRECTIONS TO DIP CIRCLES ON THE SCHULZE EARTH INDUCTOR.

Circles.	Pattern.	Correction.	Used between
23. 34	Kew-Casella*	—0. 4	1900 Jan. and 1902 June
E I 22	Wild-Edelman	—0. 2	1901 Oct. and 1902 June
1. 1	Barrow	—0. 4	1900 Jan. and 1902 June
12. 12	Robinson-Barrow	+4. 2	" "
15. 12	Kew-Casella*	—0. 8	1901 Sept. and 1901 Dec.
15. 24	"	+0. 5	1902 Jan. and 1902 June
18. 34 old	"	—1. 8	1900
18. 12 new	"	+0. 4	1902 Apr. and 1902 June
20. 12 old	"	+0. 3	1900 Jan. and 1901 Feb.
20. 12 new	"	+0. 0	1901 Apr. and 1902 June
21. 12	"	+7. 2	1900 Apr. and 1900 Aug.
21. 12	"	+7. 0	1900 Aug. and 1900 Dec.
21. 12	"	+6. 0	1901 Jan. and 1902 June
24. 12	Moureaux-Chasselon	+6. 6	1901 June and 1902 June
25. 48	Eschenhagen-Tesdorpf	—3. 6	1901 Nov. and 1902 June
56. 12	Kew-Casella	—1. 9	1900 Jan. and 1900 May
56. 13	"	—0. 5	1900 May and 1901 June
56. 1234	"	—1. 4	1901 July and 1902 June
4655. 12	"	—0. 9	1900 Jan. and 1902 June
5676. 12	"	—4. 8	1900 Jan. and 1900 June
5676. 13	"	—5. 0	1900 June and 1901 May
5677. 12	"	—2. 4	1900 Jan. and 1901 May
5678. 12	"	—4. 5	1900 Jan. and 1902 June
5678. 23	"	—1. 9	1900 Mar. and 1900 May
5678. 34	"	—1. 0	1900 May and 1900 Aug.
5678. 1234	"	—0. 8	1900 Sept. and 1900 Oct.

In this table the following notation is used: circle 23.34 means that the number of the circle is 23 and the needles used are numbers 3 and 4. E I stands for Earth Inductor. Since the above corrections were obtained, a large Wild-Edelman observatory earth inductor (see this volume T. M., p. 28) has been installed in the Cheltenham Magnetic Observatory which will hereafter be the standard dip instrument, whereas the Schulze earth inductor will be the intermediate instrument by means of which comparisons of other circles will be made. These two earth inductors and a third, referred to in above table as E I 22, agree within a few tenths of a minute with each other.

All of the Casella dip circles had been purchased by the Survey before May 1, 1899; their needles are being replaced by new ones as rapidly as circumstances warrant.

Additional comparisons made since June 30, 1902, have not materially altered the corrections of the various dip circles.

ACCURACY OF RESULTS.

An examination of the above comparisons of dip circles shows that dip results uncorrected for instrumental error may be in error by 5′ or even more. As to error of observation purely, the same comparisons

* Needles by Dover.

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show that in general the probable error of a single set (mean of two needles) does not exceed 1′. It may therefore be said roughly that dips up to 1899 are uncertain by 5′ and those since that time are probably within 2′ of the truth.

In the work of the Coast and Geodetic Survey prior to the beginning of a detailed magnetic survey of the United States it was considered satisfactory if the probable error of a resulting value of horizontal intensity did not exceed one part in five hundred. With the introduction of brass deflection bars and improved methods of observation the uncertainty has been reduced to 1/1000, and with more accurate determination of instrumental constants resulting from the intercomparison of different instruments, it may be still further reduced to 1/2000, or even less. These figures refer to a result from two sets of oscillations with two sets of deflections between, the whole operation occupying about an hour. Some further increase in accuracy can be attained by applying corrections for diurnal variation as the result of the continuous observations at magnetic observatories.

A comparison of the results of horizontal intensity observations made at the same station with the different instruments (especially at Washington, D. C.; Cheltenham, Md.; and Baldwin, Kan.) bears out the above estimated uncertainty of one part in one thousand. In the case of magnetometers Nos. 10, 20, and 21, however, the results were found to be systematically too small as compared with the other magnetometers, and all observations since April, 1901, with those three instruments have therefore been corrected as follows:

No. 10	$+0.003H$
No. 20	$+0.003H$
No. 21	$+0.008H$

The trouble with Magnetometer No. 21 (Moureaux-Chasselon magnetometer) was traced to impurities in the brass of which the magnet house is constructed, the time of vibration of the magnet differing materially when suspended in a magnetometer having a wooden magnet house. Similarly the large correction given in Table III for dip circle No. 24 (small Moureaux-Chasselon dip circle) was traced to impurities in the brass of the base and foot screws.

The above corrections constitute all that is warrantable, at present, toward reducing all intensity results to the same standard. As opportunity offers for further comparisons, however, it is intended to deduce for each instrument a systematic correction for reducing results by it to a standard instrument. The detailed results of the comparisons of the various dip instruments and magnetometers and their critical discussion will form the subject of a separate appendix.

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LIFE AND WORK OF BENJAMIN FRANKLIN.[1]

Born,	January 17, 1706
Ran away to Philadelphia,	1723
Pennsylvania Gazette started,	1729
Philadelphia Library founded,	1731
American Philosophical Society founded,	1743
Projected University of Pennsylvania,	1743
Electrical Experiments,	1746–57
Postmaster-General of America,	1753
First Mission to England,	1757
LL. D. from Oxford and Edinburgh,	1762
F. R. S.,	1775
Died,	April 17, 1790

It is impossible in the time at our disposal to give more than a bare outline of the life of Benjamin Franklin. His chief work was as a politician, statesman and diplomat, and his work in electricity was given a distinctly subordinate place in his life, being considered more as a recreation for his business hours than as a subject for life study. Before taking up his electrical experiments, an outline of his work along other lines will be given.

Benjamin Franklin was born in Boston, January 17, 1706, and died in Philadelphia, April 17, 1790. His family for three centuries had lived in the parish of Ecton, Northamptonshire, England, on a freehold of about thirty acres, and for several generations the head of the family had been the village blacksmith.

From the beginning of the Reformation the family had been zealous Protestants, and had incurred considerable danger in Mary's reign. They adhered to the Church of England until late in the reign of Charles II, when the persecution of the nonconformists caused the migration of many Puritans to New England. Franklin's Father, Josiah Franklin, was one of these emigrants, and landed in Boston in 1682, where he established himself in business as a soap-boiler and tallow-chandler.

He was twice married, having seven children by his first wife and ten by his second, of whom Benjamin was the youngest son. The second wife was the daughter of Peter Folger, one of the earliest settlers of New England, and zealously opposed to the persecution of the Quakers. As a child, Benjamin was so precocious that his father thought of sending him to Harvard to educate him for a minister; but the funds were too

[1] A portrait was published in Vol. VII, December, 1902. For the above sketch of the life and work of Franklin, the JOURNAL is indebted to Professor J. S. Ames, the sketch having been prepared by one of his students for one of his physical seminaries.

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low, and at the age of ten, after a little more than a year in the grammar school, Franklin was set to work cutting wicks and filling molds. This work was so distasteful to him that he was seriously considering the advisability of running away to sea, when he was apprenticed to his brother James to learn the printer's trade. He was an insatiable reader, and soon became interested and proficient in his trade. He wrote many ballads and songs and hawked them about the streets.

In 1721, James Franklin began publishing the "New England Courant," the third Boston and fourth American newspaper. Franklin frequently wrote anonymous articles and smuggled them into the paper without his brother's knowledge of their authorship. Many of these attracted attention, and were attributed to prominent men of the colony. Finally, for a political article which was offensive to the legislature, James was put in jail for a month and Benjamin duly threatened. Finding himself growing unpopular in Boston, and harshly treated by his brother, whom he admits that he provoked by his sauciness, he ran away in 1723, sailing in a sloop to New York. Finding no employment there as a printer, partly on foot and partly by row boat on the Delaware, he found his way to Philadelphia, and landed there with one Dutch dollar in his pocket. He found work, and soon moved to the house of a Mr. Reed, with whose daughter, Deborah, he proceeded to fall in love. Governor Keith soon noticed his good work, and offered to help him set up in business and give him the government printing. His father declined to help him, on the ground that he was too young, but the governor advised him to go to England to get a press and useful information. He did so under the governor's promise that the ship's mail bags contained letters of introduction and credit—promises not fulfilled. He found employment as a printer, and after two years of reckless living in London, returned to Philadelphia in 1726. In 1729 he began publishing the "Pennsylvania Gazette," and in 1732, "Poor Richard's Almanac."

Before going to England, Franklin had been engaged to Miss Reed; but as he failed to write to her, she became angry and married a worthless knave, who treated her cruelly and ran away to the West Indies, where he died. Feeling himself responsible for her troubles, Franklin fell in love with her again, and married her in 1730.

Soon after his return from England he started a debating society for the "Discussion of Morals, Politics, and Natural Philosophy." This society, in 1743, developed into the American Philosophical Society.

In 1731 he founded the Philadelphia Library. In 1743 he projected the university which a few years later developed into the University of Pennsylvania.

In 1736 he was appointed clerk of the Assembly of Philadelphia; in 1737, postmaster of Philadelphia; and in 1753, Deputy Postmaster General

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for the continent. Besides greatly increasing the efficiency of this department, he made it profitable.

Always interested in scientific studies, in 1742 he invented the Franklin "open stove for the better warming of rooms." While in Boston in 1746 he met a Doctor Spence, lately arrived from Scotland, and saw him perform some electrical experiments. The subject was entirely new to Franklin, and he at once became interested. The next year the Library Company of Philadelphia received from Mr. Peter Collinson, of London, a glass tube with directions for performing some electrical experiments. With this tube he began his investigations, which will be described later.

Franklin became leader of the General Assembly of Philadelphia in the controversy with the Governor during the French War, and in 1757 was sent to England to plead the cause of the assembly before the Privy Council. Before his return in 1762, he received the degree of LL. D. from Oxford and Edinburgh. His mission was successful, and on his return he received the thanks of the assembly. Two years later he was again sent to England to oppose Grenville's Stamp Act. When the Act was passed in 1765, Franklin counseled submission, and in the next ministry, that of Lord Rockingham, aided in obtaining its repeal. The next year Townsend carried his measure for taxing American imports, and Franklin was kept in England, other colonies choosing him as their representative. During his stay he made warm friendships with Burke, Lord Shelburne, Lord Howe, David Hartley, and Doctor Priestley.

Franklin's methods were conciliatory, but the independence with which he told unwelcome truths made him an object of intense dislike to the king and his friends. George III is said to have warned his ministers against the "crafty American who is more than a match for you all." Finally, in 1774, Franklin's connection with the Hutchinson affair was the occasion of an open rupture, and he was dismissed from the office of Postmaster General. About this time news of the Boston Tea Party reached England, and Franklin advised paying for the tea. Upon hearing of this, Samuel Adams remarked, "Franklin may be a good philosopher, but he is a bungling politician." Franklin remained in England a year longer to try to effect a reconciliation, but finally returned to Philadelphia in May, 1775. Next day the Pennsylvania Assembly unanimously elected him delegate to the second Congress, where he acted on the committee to draft the Declaration of Independence. He was now sent on the delicate mission to Paris, for which no other American was so well fitted. His discoveries in electricity were better known in Europe than in this country, and he was regarded by such men as D'Alembert and Diderot as the embodiment of practical wisdom. It was Turgot who said of him, "Eripuit coelo fulmen sceptumque tyrannis." He succeeded in obtaining surreptitious aid for the colonies until Burgoyne's surrender, when the Treaty of Paris was signed, almost wholly

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owing to Franklin's efforts. In 1782 informal negotiations were opened by Lord Shelburne with Franklin, which finally culminated in the treaty with the colonies. He returned to America in 1785, was chosen President of Pennsylvania, and re-elected in 1786 and 1787. In 1787 he was chosen delegate to the convention which framed the constitution. He died in 1790, and was interred with his wife and daughter in the yard of Christ Church, Fifth and Arch Streets, Philadelphia. The Dictionary of American Biography says of him: "He was at once philosopher, statesman, diplomat, scientific discoverer, inventor, philanthropist, moralist and wit, while as a writer of English he was surpassed by few men of his time."

As has been already stated, Franklin's first electrical experiments were performed with a glass tube presented to the Library Association of Philadelphia in 1746, by Mr. Peter Collinson of London. His most important work was done between this time and his departure for England in 1757. His important papers take the form of letters to Mr. Collinson and to a Mr. Kinnersley, who was associated with him in his early experiments, but later moved to Boston. His letters show clearly the extreme modesty of the man. He frequently apologizes to Mr. Collinson "for taking his time for matters which, no doubt, have already been discovered by European philosophers," but says they may furnish him with some amusement. He frequently advances hypotheses without mature consideration, inviting the criticism which he has not time to make himself. He was always ready to acknowledge a mistake or ignorance of a matter, in one letter saying, "I find a frank acknowledgment of one's ignorance is not only the easiest way to get rid of a difficulty, but the likeliest way to obtain information, and therefore I practice it. I think it an honest policy. Those who affect to be thought to know everything, often remain long ignorant of many things in which others could and would instruct them, if they appeared less conceited."

Franklin's first original experiments were with fine points. In a letter dated July 11, 1747, he describes them. If a light cork ball be suspended so as to touch a charged shot, it will be repelled, but if a sharp needle be brought up within six or eight inches, the repellency is destroyed, while a blunt object must be brought to within an inch and draw a spark. If this be done in the dark, a light like that of a glowworm appears about the point at the distance at which the repellency is destroyed. If a needle is laid on the charged shot, the cork comes back at once, showing that the point throws off, as well as draws off, the electricity, and while the needle lies on the shot, the latter can not again be charged. A more convenient electric machine was soon made, consisting of a glass sphere rotating on an axis. He soon discovered a positive and negative state of charge when he charged a man standing on wax, he himself standing on wax and rubbing the tube. Either one

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could draw a spark from a person on the floor, but a stronger one from each other. From this he reasoned that electrical fire is a common element, and each of the three persons has his equal share. Some of this, however, is drawn from one and forced into the other, so that one has less than his normal quantity, or a minus amount, while the other has more, or a plus amount.

The next investigation was with Leyden jars or bottles. He found that the non-electric in bottles differs from a non-electric outside, since the electrical fire of the latter is accumulated on the surface, and forms an electrical atmosphere about the non-electric, while in the former case it is all collected in the substance of the glass. His theory of the charge was as follows: A given jar contains a normal amount of electrical fire, say twenty units. It can contain no more than this, and when a unit is put into the upper part a unit must go out of the lower part. When the jar is completely charged, there are twenty units in the upper part and an electrical vacuum in the lower. If you try to drive in more through the top, you burst the glass. You can not get any out at the top unless an equal amount can get in at the bottom. This experiment reads wonderfully like Maxwell's displacement theory. Franklin could not understand what prevented the compressed fluid in the upper part of the jar from expanding and filling the vacuum instead of having to go around the outside.

In 1748 he had analyzed his Leyden jars, and proved that the fire resided in the glass. He did this by pouring out of a charged jar the water which formed the inner conductor and putting in some fresh water, replacing the outer coating, and then discharging the jar. He distinctly states that the words charge and discharge are used only for convenience, since the amount in the jar is always the same. Otherwise a man discharging the jar would be himself charged if he stood on wax. In this year he constructed two electric motors. One was a wheel supported horizontally, with thirty radii, each having a thimble at the end. On one side was placed a jar charged through the hook, and, on the other, one charged through the coating. The wheel would revolve until the jars were discharged. The other motor was a thin glass disk, with coatings above and below. Lead bullets placed around the edge were connected alternately with the upper and lower coating, and thimbles were mounted on glass rods so as to be near the bullets as they revolved. This wheel revolved very rapidly when the two coatings were connected to charged jars, and continued in motion for an hour. Such was the power of the machine that the weight of one hundred Spanish dollars, with which it was once loaded, did not perceptibly impede its motion. He proposes to complete the work of the winter by "a picnic at which turkey is to be killed by the electrical shock and roasted by the electrical jack before a fire kindled by the electrical bottle, and the

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health of the famous electricians of Europe is to be drunk in electrical bumpers under the guns of an electrical battery."

In his next letter he explains in detail his reasons for believing that lightning is an electric spark, and advances his theory, explaining the presence of the fluid in the clouds. Electricity is generated by the rubbing of an electric against a non-electrtc. The sea consists of little particles of salt rubbing against particles of water, and thus the fluid is generated. As the water evaporates, the particles carry this fluid with them to the clouds. The objections to this theory were so great, however, that he soon abandoned it. In 1750 he explained his theory of the constitution of the electric fluid, and proposed a method of testing the theory that lightning was electricity. The fluid, he thought, was an element whose particles repelled each other, and were so small that they could penetrate and permeate any substance just as water does a sponge. The particles differ from those of ordinary fire in that they can exist with water, while when water comes in contact with ordinary fire, it is evaporated, and each particle carries off a particle of the fire until it is all carried off. To test his lightning theory, he proposed to erect a sort of sentry box on some suitable tower, and extend a sharp point as far as possible into the air as a thunder cloud was passing. The electricity could then be collected and tested, as was done subsequeutly in the kite experiment. Unfortunately, there was no suitable tower available in Philadelphia. In this letter he also explains the reasons why electrics and non-electrics should be called non-conductors and conductors.

It was in December, 1750, that Franklin described an experiment which he performed accidentally. While talking to some friends, he discharged through his body two six-gallon jars which were intended for a turkey. He felt what he described as a universal blow, but saw no spark and heard no report. He concluded from this that the velocity of the discharge is greater than light, sound, or human sensation. On another occasion he received a shock through the head, but did not even feel the blow. Hence he concluded that death by electricity is painless.

In 1752, Mr. Kinnersley communicated to Franklin the discovery that a sulphur globe will give electricity different from the glass globe. Franklin verified the observation, and repeated many of his experiments for the purpose of determining which was positive and which was negative. He had great difficulty in determining, but finally decided that that from the glass was positive and that from the sulphur negative, since the former exhibits a larger, longer, more diverging and snapping brush than the negative, and appeared to be throwing off the fire. The cool breeze from the point was also stronger.

In June, 1752, Franklin carried out the famous kite experiment. The experiment had been performed a month earlier by M. Dalibard, at Marly, France, in the way originally proposed by Franklin, and to

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Franklin belongs all the honor of the conception. In September, of the same year, he erected an iron rod to draw electricity down into his house, and arranged two balls to give notice when it was charged. He found that the clouds were usually charged negatively, which was what he expected. According to his theory, for a given state of a body there was a normal quantity of electricity which it would contain, just as a sponge contains a given amount of water for a given compression. Water, which was saturated as a liquid, was far below saturation when evaporated, or was charged negatively. He tried the experiment of evaporating water on a hot plate, but could find no charge on the plate or in the steam, nor could he explain why the vapor should not receive its full charge at the instant of leaving the liquid. He could not explain, either, the occasional presence of a positively charged cloud. At this time he proposed the use of lightning rods in the form of rods terminating in sharp points to draw off the electricity, and so avoid a stroke, or to conduct away the electricity if the stroke be unavoidable. The rods were erected on various houses, and effects carefully noted. For these discoveries he was awarded the Copely medal by the Royal Society in 1753.

In this year it was proposed to Franklin to measure the velocity of an electrical disturbance by connecting by a wire two springs near together, one flowing into the Potomac, the other into the Ohio, and find the time taken to go around by way of the Gulf of Mexico. Franklin explained that the current would not go that way anyway, but compared the flow to the flow of an incompressible fluid in a pipe. The moment you put more in at one end you get an overflow at the other.

In 1757 some experiments were made in Europe to find the effect of electricity on paralytic patients, and some success was reported. Patients flocked to Franklin to have the new remedy tried, and for four or five days improvements were noted, but they seemed to stop at a certain point. Franklin remarks that possibly, with a skilled physician and many slight shocks instead of the three or four heavy ones per day, cures might be effected.

In 1757 Franklin was sent to England on his first mission, and this practically brought to a close any extensive original experiments. He wrote many letters from London, and later from France, answering questions and explaining more fully his theories and the practical advantages of the lightning rod. In the little leisure time that he had, he discovered that there was no charge on the inside of a charged tin can, and made some observations on the behavior of a tourmalin when heated. He advised his friends to avoid trees during thunder-showers for two reasons: first, the tree attracts the lightning; and second, if one is in the open field, his clothing is more likely to be wet, so that if one is struck in the head, the electricity will flow off through the clothing

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without harm. This hypothesis was verified on two rats; the dry one was killed, the wet one only stunned. He advised the use of electricity for killing old turkeys, as it made the flesh tender by exploding the liquid in the tissues, and so rending them. He found that a Leyden jar, hermetically sealed, would keep its charge for several months with scarcely any diminution if kept cold, but if heated, the glass allowed the passage of the current.

In one of his letters, Franklin states that he is not working to gain reputation as a philosopher, and his letters throughout show that he was actuated only by an interest in his work, and the desire to make some useful invention. His friend, Mr. Collinson, was a Fellow of the Royal Society, and succeeded in having some of Franklin's letters read. At first they were only laughed at, and were not even given a place in the Proceedings. Later, Franklin requested that they should not be published until he had time to edit them more carefully. He never found time to do this, however, and Mr. Collinson had the early papers published in London by themselves. They were translated into French, German, and Latin, and won for Franklin a high position among scientists.

Franklin wrote his own biography down to the date of his landing in London in 1757. The best edition is that of John Bigelow, Philadelphia, 1868. His works were edited by Jared Sparks, and published in ten volumes, Boston, 1850. A new edition containing material from new manuscript, was edited by John Bigelow, ten volumes, New York, 1887. There are several good lives in English, French, and German.

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LETTERS TO EDITOR

DISCONTINUANCE OF CO-OPERATION IN MAGNETIC WORK WITH THE BRITISH ANTARCTIC EXPEDITION.

Previous to the departure of the "Discovery" to the Antarctic, it was arranged here by Mr. Bernacchi, in charge of the magnetographs of the "Discovery," and Dr. Farr of this observatory, with the approval of Captain Scott, that magnetograph records at quick speed should be made for twenty-four hours on the first and fifteenth of the month until the return of the Expedition. Several obsevatories undertook to co-operate in this work. Mr. Bernacchi writes that he has been able to do this so far while in winter quarters, but in consequence of his supply of fast photographic paper being insufficient, he will not be able to continue these records this winter. The co-operating observatories, Mauritius, Batavia, De Bilt, and Kew, have been advised of this and asked to discontinue likewise.

HENRY F. SKEY.
Pro Dr. C. C. FARR.

CHRISTCHURCH, NEW ZEALAND,
MAY 5, 1903.

CONTINUANCE OF INTERNATIONAL CO-OPERATION IN RAPID REGISTRATIONS DURING SPECIAL TERMS.

Although the program for international co-operation in connection with the Antarctic Expeditions, as published,[1] terminated on Feb. 15, last, it was deemed best, in the absence of official advice, by the Coast and Geodetic Survey magnetic observatories to continue the work, as outlined for the 1st and 15th of each month, a little while longer. An official inquiry was directed to the German Government through the German Embassy at Washington to which after several months a reply was received to the effect that the German Government would be glad to have the United States observatories co-operate for another year and that the work was to be timed and arranged in accordance with the program for the period February 1, 1902, to February 15, 1903.

Dr. Schmidt, in charge of the Potsdam magnetic observatory, replying to an inquiry from the Editor of the Journal briefly writes: "The Potsdam observatory on June 1st will resume the special term observations, beginning with rapid registration one-half hour before the required hour and continuing until one-half hour after the hour, hence for two hours—

[1] See T. M., Vol. VI, p. 49.

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thus beginning on June 1st, rapid registration from 7^h 30^m to 9^h 30^m a. m., Greenwich mean time, June 15th, from 8^h 30^m to 10^h 30^m, etc., etc. I shall continue the observations as long as it is done at other observatories."

In accordance with this advice, the Coast and Geodetic Survey is at present carrying on rapid registration work on the 1st and 15th of each month at its five observatories—Cheltenham (Maryland) Baldwin, (Kansas), Sitka (Alaska), near Honolulu (Hawiian Islands), and Vieques Island (Porto Rico).

In conclusion, I may remark from certain experiences during the past year with regard to getting necessary information promptly that international work can be conducted much more satisfactorily through individuals, or well-known committees, than through government embassies.

L. A. BAUER.

U. S. COAST AND GEODETIC SURVEY.

CONCERNING OBSERVATIONS OF TERRESTRIAL MAGNETISM AND CLOUDS CARRIED OUT AT NORWEGIAN STATIONS DURING THE YEARS 1902–1903.

The observations carried out at two of the Norwegian Northern-Light Expedition's stations, Dyrefjord in Iceland, and Bossekop in Finmark, have lately been concluded, but the work will be continued at the stations in Novaya Zemlya, and Spitzbergen, until the end of June.

Even now, by comparing the daily magnetic photograms obtained at Dyrefjord, and Bossekop, with those of earth currents from the latter, extremely interesting results have been obtained.

It was in order to solve, in the best possible manner, the problem placed before us, viz., the determination of the connection existing between terrestrial magnetic perturbations, aurora borealis, and cirrus clouds, that I, in a circular dated May, 1902,[1] took the liberty of requesting your kind assistance. In order to obtain the most complete collective views of the matter, it is necessary to procure copies of a certain number of the daily recorded photograms of magnetic variations, if possible, from all quarters of the globe.

After comparing photograms from Bossekop with corresponding ones from Potsdam, I selected thirty days, on which general magnetic disturbance was great, as those which most suited my purpose, and I have, consequently, determined to adopt these as the basis of my investigations. I now take the liberty of asking all those who are in a position to do so, to give or lend me copies—photographic preferred—of photograms of magnetic disturbances that may have occurred on those thirty days, and urge them, in the interests of science, not to mind facing the considerable amount of trouble which must be undertaken in order to fill such a

[1] See T. M. Vol. VIII.

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request; and, if required, I am willing to refund any expense necessarily incurred in connection with it. In the work that I intend to publish, I shall reproduce, so far as I can by photography, a very large number of such photograms after they have been reduced to a uniform scale as regards time, so that any one may be able to check the results arrived at, by me, from my manipulation of the materials to hand.

The variations of most value for my work, are those of the two horizontal elements. In respect to the thirty days in question, when the vertical intensity shows marked variations, it will be, likewise, very important to me to obtain copies of photograms relating to vertical intensity. The thirty days I have chosen are given further on, while the Greenwich mean time of the most interesting part of the variations is likewise indicated, and I want to obtain copies of photograms comprising intervals of, at least, six to eight hours before and after this time.

5 Oct.	1902	9^h	P. M.	Greenwich Time.	13 Dec.	1902	5^h P. M. Greenwich Time.
6 —	"	9^h	—	—	15 —	"	1^h A. M. —
7 —	"	10^h	—	—	22 —	"	10^h P. M. —
8 —	"	9^h	—	—	23 —	"	8^h — —
11 —	"	9^h	—	—	24 —	"	6^h — —
25 —	"	1^h	A. M.	—	26 —	"	9^h — —
27 —	"	7^h	P. M.	—	6 Jan.	1903	6^h — —
28 —	"	8^h	—	—	12 —	"	6^h — —
31 —	"	1^h	A. M.	—	26 —	"	10^h — —
10 Nov.	"	10^h	P. M.	—	8 Feb.	"	7^h — —
21 —	"	9^h	—	—	10 —	"	11^h — —
23 —	"	11^h	—	—	15 —	"	4^h — —
26 —	"	4^h	—	—	1 Mar.	"	11^h — —
9 Dec.	"	4^h	—	—	22 —	"	10^h — —
11 —	"	8^h	—	—	31 —	"	1^h A. M. —

In addition to such copies it would be very desirable to obtain the loan of all the photograms, taken by the observers who promised to partake in the special and rapid registrations, from the 2d to 8th December, 1902; 2d to 8th January, and 3d to 9th February, 1903. In order to be able to employ, for my purpose, the copies, and photograms referred to, it is necessary that the hours at which they were taken be stated with the greatest possible accuracy, and also the value of the base line, and that of the millimètre of the ordinates of the curves.

I also beg to request the staffs of meteorological stations at which those observations referred to in my circular of May, 1902, have been kindly effected, to now conclude the observations, and provided such has not already been done, forward me the results obtained.

I have, already, received from many stations most valuable material —and for those my thanks are due—but, as everybody will easily understand, it is necessary to obtain observations from a vast number of stations in order to gain somewhat complete general views of the matter in question.

KR. BIRKELAND.

CHRISTIANIA, JUNE, 1903.

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SOME MAGNETIC OBSERVATIONS IN MEXICO.

I have the pleasure to communicate the following data that I obtained in an expedition to the northern frontier in the month of July of last year:

RESULTS.

Station.	Latitude.	Longitude W. of Gr.	Altitude.	Date.	E. Decl'n.	Incl'n.	Intensity		
							Hor'l.	Vert'l.	Total
			Meters	1902			γ	γ	γ
Chihauhua	28°38′.4	106°04′.5	1423	July 12, 13, 14	10°31′.0[1]	55°50′.6	29393	43320	52352
C. Juarez	——	——	——	July 23	——	59 21.0	——	——	——
Jimenez	27 06	104 57	——	July 27	9 57.6[2]	——	30304	——	——
Zacatecas	22 46.6	102 34.4	2443	July 29	8 57.3[3]	——	31947	——	——

In Juarez City, I did not determine D and H because of the electric railways. In Jimanez and Zacatecas, I and Z are wanting as the dip circle was somewhat injured in transportation over bad roads. All the observations were made in the field outside the cities. In my former letter I mentioned to you that the value of I that I am obtaining in Cuajimalpa is something like 20′ higher than the last that was determined here before the installation of the electric railways and which I attribute to some defect in the dip circle that I am using (Fauth, model of Kew).

M. MORENO Y ANDA.

TACUBAYA, MEXICO, JUNE 4, 1903.

[1] Between 9 and 11 a. m.

[2] Mean of observation at 8 a. m. and 2 p. m.

[3] At 10 a. m.

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J. J. THOMSON.

Joseph John Thomson, D. Sc., F. R. S., Cavendish professor of experimental physics in the University of Cambridge, was born near Manchester, 18th December, 1856. He entered Owens College in that city as an engineering student in the session 1871–2. He distinguished himself in this course, but gave it up after the first two years and specialized in mathematics and physics, in which his interests had become centered. In 1876 he went to Trinity College, Cambridge, and studied for the Mathematical Tripos, becoming second wrangler and second Smith's prizeman and Fellow of Trinity in 1880. (The senior wrangler and first Smith's prizeman in that year was Professor T. Larner, the successor of the late Sir George G. Stokes in the Lucasian chair of Mathematics at Cambridge.)

In 1883 he was appointed Lecturer at Trinity and won the Adams prize in the university for his well-known "Treatise on the Motion of Vortex Rings." In the following year he was elected Fellow of the Royal Society and was appointed to the Cavendish professorship of physics, in which chair he continues so ably to maintain and extend the traditions established by his predecessors, Maxwell and Rayleigh.

One of his courses of lectures, "Applications of Dynamics to Physics and Chemistry," was published in 1886. In 1891 he prepared the third edition of Maxwell's Treatise on Electricity and Magnetism and found it necessary to write a supplementary volume to bring the work up to date. This appeared in 1892 under the title "Recent Researches in Electricity and Magnetism" and is especially noteworthy in its discussion of the discharge of electricity through gases. He continued the consideration of this latter subject in the lectures which he gave at Princeton University on the occasion of its centenary and which have since appeared in book form.

When the X-rays were discovered, he was able to bring them within the scope of Maxwell's Electro-magnetic theory and his subsequent investigations on the ionization of gases and on the nature of the cathode rays have opened up a new field of research on the ultimate relations of matter and electricity and on the phenomena of radioactivity. Numerous contributions on these fascinating subjects by himself and his pupils are to be found especially in the pages of the *Philosophical Magazine* for the last few years. In consideration of this work the Hodgkins prize of the Smithsonian Institution for the most valuable contribution to our knowledge of atmospheric air has been awarded to him this year.

He has recently developed a new theory of the arc and spark

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discharge and an electrical theory of mass, which formed the subject of the Silliman lectures which he gave at Yale University in May and of a subsequent course at the Johns Hopkins University in June, of the present year. These lectures will be contained substantially in his new book which is now in the press and will appear shortly.

In 1890 he married Rose Elizabeth Paget, daughter of the late Sir George E. Paget, K. C. B. In 1894 he was President of the Cambridge Philosophical Society and in 1896, President of Section A, British Association for the Advancement of Science and since then various other honors have been bestowed upon him.

Besides the works already mentioned he has published "Elements of the Mathematical Theory of Electricity and Magnetism," 1895, and in collaboration with Professor J. H. Poynting, a "Textbook on Physics" of which two volumnes on "Sound" and "Properties of Matter" have already appeared.

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NOTES

11. *The French Association for the Advancement of Science*, which meets at D'Angers from August 4–11, will discuss in the seventh section (Meteorology and Geophysics), papers relating to terrestrial magnetism, seismology, and atmospheric electricity.

12. *The Second International Seismological Conference* meets at Strasburg, from July 24–28, 1903, and will have an interesting program of subjects to discuss. Professor Harry Fielding Reid, of the Johns Hopkins University, will attend as the official delegate from the United States.

13. *The British Association for the Advancement of Science* meets at Southport, September 9–16, under the presidency of Sir Norman Lockyer. Captain E. W. Creak is chairman of Section E (Geography).

"It has been arranged that the *International Committee for Meteorology*, the members of which are representatives of official meteorological organizations in all parts of the world, shall meet at Southport during the session of the British Association. The Committee has not met in England since 1876; its last regular meeting was at St. Petersburg in 1899. The Local Committee of the British Association hope that the meeting of the International Committee at Southport may be the occasion of an increased attendance of distinguished guests at this meeting of the Association."

14. *Magnetic Survey of the Dutch Archipelago.* Dr. van Bemmelen writes that the Dutch government has granted the means for a new survey during the years 1904–1907. During each of these years the field work is to cover two to four months, only a general survey being possible with the present means. A beginning has already been made, observations having been made on the "tin island," Billiton, and at some points in the neighborhood of Batavia, and it is also hoped to secure values at different stations in Java partly to obtain early information regarding the secular variation.

On Billiton Island, van Bemmelen had the opportunity to study the magnetic effect of a natural wall of lodestone 100 m. long and 2 m. thick, and from 1–4 m. high, emerging from the top of a hill in the forest.

15. *Magnetic Work executed by the Coast and Geodetic Survey from July 1, 1902, to June 30, 1903.* The work may be summarized as follows:

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A. MAGNETIC SURVEY WORK.

The magnetic elements were determined at 461 stations distributed over numerous States, 10 of the stations being in Alaska, 9 in Porto Rico, and 16 in the Philippines, Cuba, and Santo Domingo. The principal work was done in Arizona (54 stations), Florida (26), Kansas (49), Louisiana (15), Maryland (18), Michigan (14), Nebraska (19), Ohio (19), Pennsylvania (52), and Texas (72).

By December of this year, owing to the progress already made, the magnetic survey of the area bounded by latitudes 35° and 41°, and longitudes 75° and 85°, embracing the States of Pennsylvania, New Jersey, Delaware, Maryland, Virginia, West Virginia, Ohio, North Carolina, and the eastern portions of Kentucky and Tennessee, will be completed, and the results at once submitted to a careful discussion, with the view of ascertaining what improvements, if any, are needed in the methods of work, to bring out all of the practical and scientific purposes of a magnetic survey.

The work in Louisiana was done in co-operation with the State Geological Survey.

B. OCEAN SURVEY WORK.

In January, 1903, a Lloyd-Creak dip circle was mounted on the Coast and Geodetic Survey Steamer "Blake," and observations made on the trip to Porto Rico and return. Some compass work has also been done by the other vessels of the Survey. The work has largely been of an experimental nature as yet. It has been demonstrated, however, that if the proper precautions are taken, valuable results may be secured. The Lloyd-Creak dip circle has been proved to be a most satisfactory instrument both for land and sea work.

C. MAGNETIC OBSERVATORY WORK.

The four magnetic observatories situated at Cheltenham (Maryland), Baldwin (Kansas), Sitka (Alaska), and near Honolulu (Hawaiian Islands), have been in continuous operation throughout the year. Owing to various improvements being made in the vertical-force instrument, only the first named observatory is provided with such an instrument, and, in fact, at this observatory a double set of photographic instruments are in operation (Adie pattern and Eschenhagen pattern).

In February, 1903, a temporary magnetic observatory was established in Fort Isabel, Vieques Island, Porto Rico, and since March registrations of declination and horizontal intensity have been secured.

D. SPECIAL INVESTIGATIONS.

A variety of special investigations have been made, embracing experimental work in the field and at the observatories and theoretical investigations at the office.

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E. EXPEDITIONS.

Besides the work of the Survey proper, two expeditions have been fitted out with magnetic instruments, and the observers given the necessary training and furnished with the requisite data and instructions; viz., the Ziegler North Polar Expedition, W. J. Peters being in charge of the magnetic work, and the Bahama Expedition of the Baltimore Geographic Society, O. L. Fassig being in charge of the magnetic work.

F. PUBLICATIONS.

1. United States Magnetic Declination Tables for 1902, and Principal Facts Relating to the Earth's Magnetism. By L. A. Bauer, Washington, 1902.

2. The Magnetic Observatories of the United States Coast and Geodetic Survey in operation on July 1, 1902. By L. A. Bauer and J. A. Fleming. Appendix 5, Report of the Superintendent (O. H. Tittmann) of U. S. Coast and Geodetic Survey for 1902.

3. Magnetic Dip and Intensity Observations, January, 1897, to June 30, 1902, by D. L. Hazard. Appendix 6, Report of the Superintendent (O. H. Tittmann) of the Coast and Geodetic Survey for 1902.

4. Results of International Magnetic Observations made during the Total Solar Eclipse of May 18, 1901, including Results Obtained During Previous Total Solar Eclipses. By L. A. Bauer. Published in TERRESTRIAL MAGNETISM, December, 1902.

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ABSTRACTS AND REVIEWS.

H. A. LORENZ'S "SICHTBARE UND UNSICHTBARE BEWEGUNGEN."[1]

This book consists of seven lectures delivered in the early part of 1901 in Holland before a popular audience. The subjects are: Rectilinear Motions, Curvilinear Motions, Vibratory Motions, and Rays of Light, Light Vibrations, Molecular Motion, Electrical Phenomena, and the Conservati n of energy.

One can not help wondering whether the subject of kinematics would draw a large audience, even in Holland. Certainly many lecturers would hesitate a long while before venturing upon such subjects as those of the first two lectures. After reading them, however, the wonder becomes how they could ever have been suspected of dryness. The beautiful logical sequence, the range of thought from molecule to fixed stars, and the novelty and aptness of illustration contribute largely to this result. The formula, $F=ma$, is, for example, applied to the case of a brass ball of 800 g. mass swinging against another ball of equal mass. The time of contact being .0002 sec., the force acting is calculated to be the weight of 600 kg.

In the second lecture, the path of a body thrown slantingly upwards is made to serve very happily as an introduction to motion in a circle. The subsequent lectures lend themselves more readily to being made interesting and thus Professor Lorentz's success is more easily won, though no less marked. The treatment of the kinetic theory of gases in the fifth lecture is especially worth reading. The reader will feel regret that the author did not distort the perspective of his treatment by amplifying the discussion of the Zeeman effect in the next and last lecture.

No doubt the loose definition of phase on page fifty-eight was a concession to the audience.

When a scientific man of Professor Lorentz's high standing takes the trouble to make some part of his knowledge clear to people in general, he deserves the thanks not alone of those to whom new vistas have thus been opened, but also of his fellow-workers, for he has helped to keep abstract science and common life in touch with each other.

To find a better example of how science ought to be popularized would be a hard task. It is to be hoped that Professor Lorentz may find time to prepare other courses of similar lectures, when he is not engaged in elaborating the theory of electrons, and that the book just received may be translated into English.

G. F. STRADLING.

NORTHEAST MANUAL-TRAINING SCHOOL, PHILADELPHIA, PA.

[1] Translated from the Dutch by G. Siebert. Vieweg und Sohn, 1902, 8°, pp. 123. Price 3 Marks.

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ON THE RADIO-ACTIVITY OF GROUND AIR.[1]

Professors Elster and Geitel, having previously shown that any conductor becomes radio-active if charged negatively and exposed to the air, and that the effect is much greater when the conductor is exposed to the air in a cellar which has been kept closed, they have now made experiments to determine the source of the radio-activity in subterranean chambers. Their first thought was that possibly any mass of air would show an increase in its conductivity and radio-activity, if confined in a closed vessel, and indeed some such effect is shown by small inclosed volumes of air, but careful quantitative experiments on air contained in a large unused steam boiler showed that this could not account for the activity of cellar air. Next it was necessary to examine the material of the cellar walls and the surrounding earth. These, when tested, gave no indication of radioactivity. Finally it occurred to them to introduce a pipe 1½ meters into the earth of a garden and draw out through it air which had been contained in the ground, this air then passing into a large bell jar to be tested. One of their "loss of charge" leaf electrometers in the testing jar at once showed the remarkably high conductivity of this ground air. Furthermore, experiments with negatively charged conductors showed that this air possesses the power of imparting radioactivity in a much higher degree than even the air from cellars. The ground air loses its radio-active properties very slowly, so that it may be collected in any suitable vessels and afterwards transferred to the testing vessel containing the electrometer. In one case the conductivity of the air fell off only a fifth from the maximum in forty-eight hours. In a closed vessel the conductivity is influenced by the secondary activity imparted to the walls, so that the maximum is not attained for several hours.

Their results are most interesting when considered in connection with a paper by Professor J. J. Thomson published about the same time (Phil. Mag., Sept., 1902.) Professor Thomson discovered that air which has been bubbled through water, air into which water has been sprayed, and air which in any way has come into intimate contact with water, shows radioactive properties which are very similar to those of the cellar and ground air of Professors Elster and Geitel, so it seems probable that the activity of the ground ai ris due to the action of the ground moisture on the air as it is drawn through the soil. Tests of air drawn through small bodies of dry and moist earth should decide this point. In any case, Professors Elster and Geitel have established their conclusions that the abnormal activity of cellar air is due to the exhalation of the very active ground air from the surrounding earth, and that the ionization and radio-activity of the general body of air near the earth is to be referred to the same cause, though in the higher air strata other causes, such as the Sun's rays, may be operative.

G. B. PEGRAM.

THE CONCENTRATION OF RADIO-ACTIVE EMANATIONS IN LIQUID AIR.[1]

In the spring of 1901 it was found in Professor Ebert's laboratory that when liquid air is allowed to evaporate into a vessel containing suitable means for testing the electrical conductivity of the air, no abnormal conductivity is

[1] ELSTER, J. AND GEITEL, H. Ueber die Radio-activität der im Erdboden enthaltenen Luft. Repr. from Physicalische Zeitschrift. 3. Jahrgang. No. 24. Sept. 15, 1902. 4 pp.

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shown until the air has all evaporated, when suddenly the conductivity rises very much to a maximum, then undergoes a slow decrease. After carefully proving that the increase in conductivity is not due to the mere boiling of the liquid air, to any action of ice or other solid particles present therein, to any radio-active matter from the condensing apparatus, or to electrified particles present in the liquid air, the author is satisfied that the true explanation is, that the gaseous radio-active emanation, always present in small quantity in the air, is condensed at a temperature above that of liquid air, and that at the temperature of liquid air its radioactive power is latent, only coming into action again when the emanation is allowed to pass into the gaseous form. In this latter point the atmospheric emanation is different from the radium and thorium emanations, which, as Rutherford has shown, continue to decrease in activity with the time, even at temperatures many degrees below their respective points of condensation.

This conserving of the emanation at liquid air temperatures renders it possible to concentrate it very much; to do this it is only necessary to nearly evaporate successive portions of liquid air in the same vessel. Experiments were made on air from various sources: fresh air, ground air (which contains the emanation in relatively large quantity), cellar air, air that had been in intimate contact with water, and air taken in during a rain-storm. In most of the work, the air was liquefied in a condenser surrounded by liquid air under reduced pressure. A definite number of liters of the air to be tested being liquefied, the liquid was evaporated to a definite number of c.c., and the products of further evaporation passed through a system of absorption tubes (potash, chromic acid, sulphuric acid) and through a strong electric field between two coaxial cylinders (to remove any particles carrying free charges) into a glass bell jar of 60 liters capacity, which had previously contained air freshly taken in from the open. Under the bell jar was an Elster-Geitel loss-of-charge apparatus, by means of which the air conductivity before and after the introduction of the evaporated air could be measured. The loss of potential, in volts, which the charged body suffered in 15 minutes was taken as a measure of the conductivity.

With fresh air in the vessel, the loss was 11 to 17 volts, depending on atmospheric conditions, in 15 minutes. After standing, a maximum of 23 to 34 was reached in about a day, then there was a gradual decrease. 107 c.c. of freshly liquefied air evaporated under the bell jar gave during evaporation 18 to 19 until all the air was evaporated, then rose to 21 to 23 after 5 hours, 37 to 39 after 7 days; 107 c.c., remainder from the partial evaporation of 6 liters of the liquid air when allowed to evaporate under the bell jar, gave about normal conductivity values until the air was all evaporated, then rose rapidly to over 5 times the normal value, 7 hours after the evaporation. After reaching this maximum, the conductivity fell off rapidly, afterwards more and more slowly. After 100 hours it was 65 against 81 at the maximum; after 410 hours it was only 39.

Air drawn out from the ground gave similar results, except that the conductivity was in all cases far greater, the potential of the charged body

[1] H. EBERT. Ueber die Möglichkeit radio-aktiverende Emanationen in flüssigen Luft anzureichern. Repr. from Sitzungsberichte der Math.-phys.klasse der Kgl Bäyer. Akad. d. Wiss. Bd. XXXIII, 1903, Heft I; Eingelaufen 7. März.

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falling in some cases at the rate of 1,000 volts in 15 minutes. By taking two equal portions of the liquefied ground air, testing one as above and keeping the other liquefied for 75 hours before testing, it was found that the radio-activity is not lost nearly as rapidly in the liquid as in the gaseous state. Indeed, it appears to be completely conserved. Curves showing the change of conductivity with time, for the air from the evaporation of liquefied ground air, are given. The walls of the vessel in which the ground air stands become slightly radioactive. Usually the rates of dissipation of + and — charges in the air are not the same, so a discussion of the probable causes of the variation in the rates is given. Experiments show that ground air is more radioactive during a period of falling barometer, doubtless because the air has come from greater depths.

Following up the work of Sella and Pocchettino and J. J. Thomson on the radio-activity of air blown through water, experiments were made on air sent over and over again through a water blast, using 8¼ liters per minute. When a certain volume of this air was sent through the drying tubes into the testing vessel, the conductivity rose to 160. If, however, this air on its way to the testing vessel had to pass through a condenser surrounded by liquid air, the conductivity was very little above the normal. When later the condenser was allowed to rise in temperature, and fresh air passed through it into the testing vessel, the conductivity again rose to 160 to 170. Thomson had previously shown that the radio-active matter in air that had been shaken up with water could not pass through a tube surrounded by a carbon dioxide ether mixture, but had not shown that the radioactive matter could be regained. A slight amount of radio-activity was detected on the walls of the vessel after this water-treated air had been standing in it. It seems probable that the radio-active matter is originally dissolved in the water, and in the water-blast process is only transferred to the air; a view which is in accord with the most recent work of Thomson on the radio-active gas present in water.

Interesting details of the experiments, references to the work of others, and pertinent suggestions are contained in the paper, which concludes with a discussion of a method for determining the essential constants of a radio-active emanation, so far as they can now be considered, from a single series of measurements on the conductivity of the air containing the emanation.

COLUMBIA UNIVERSITY, NEW YORK. GEO. B. PEGRAM.

MESSUNGEN DER ELECTRICITÄTSZERSTREUUNG IN DER FREIEN LUFT.[1]

In this paper the results of seventeen months' observations are collected and discussed with a view to ascertaining whether there is any relation between the electrical conductivity of the atmosphere and other meteorological phenomena. The discussion is wholly based upon the ion theory of conductivity.

Observations were made daily at Wolfenbüttel between 11 a. m. and

[1] J. ELSTER AND H. GEITEL. Sitzber. Kais. Acad. d. Wiss, Wien, Math.-natur. classe Bd. CXI abth. IIa, Juli, 1902, Pp. 1-36.

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1 p. m., and in addition to the electrical records careful note was made of the transparency of the air and other weather conditions, and these records were amplified by referring to the records of neighboring regular meteorological stations.

The results are summarized as follows:

1. At Wolfenbüttel, with protected dispersion cylinder, the conductivity coefficient has a value of 1.33.

2. The dissipation of negative electricity is greater than of positive (Probably due to Earth's field.)

3. There is no well marked dependence, of conductivity, upon air temperatures.

4. Or upon relative humidity.

5. But conductivity does vary directly with the "saturation deficit" of water vapor in the air.

6. Impurities in the air exert a strong influence, and conductivity decreases upon the appearance of fog, smoke and dust.

7. Conductivity is greatest when the wind has a northerly component.

8. As the force of the wind increases, conductivity generally becomes greater. Squalls from N. or N. W. cause high conductivity.

9. On days with steady weather conditions, the maximum conductivity occurs about noon.

10. The annual variation shows greatest conductivity in April and least in January. L. G. SCHULTZ.

ÉTUDE DE L'ÉLECTRICITÉ ATMOSPHÉRIQUE AU SOMMET DU MONT BLANC, (4810 M) PAR BEAU TEMPÉRATURE.[1]

This paper embodies the results of an investigation which was carried on from August 31, to September 3, 1902, during a period of fair weather with southerly winds.

The records consist of:

1. The continuous registration of the diurnal variation of the electric potential at a point in air above the ground, with respect to the potential of the ground.

2. A series of direct measurements of the normal potential gradient (Volt/Meter) between two points in the air above a small horizontal snow-covered plane on the summit.

3. A series of measurements of the dissipation of positive and negative electrical charges in free air, near the ground.

The potential measurements show that: In fair weather with a south wind, near the autumnal equinox, the electrical field near the earth, on the summit of Mont Blanc, has a potential gradient of about +550 V/M; its daily curve exhibits a simple oscillation with a maximum of 700 to 1000 V/M between 3 p. m. and 4 p. m., and a minimum of 100 to 200 V/M about 3 a. m.

This confirms the general law of the variation of the Earth's field as deduced by A. B. Chauveau in his discussion of the Eiffel Tower observations.

The measurements of the dissipation of electrical charges in free air gave high values of q, as the loss of the negative charge was generally ten times as

[1] G. LE CADET. Comptes Rendus.

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great as that of the positive. The q curve falls gradually to a principal minimum at 11 a. m., rises sharply to a principal maximum at 1.46 p. m., falls to a secondary minimum at 2.41 p. m., rises sharply to a secondary maximum at 3.07 p. m. and then it falls slowly to the night hours Comparitive observations were made on September 4th in a valley, under nearly the same atmospheric conditions, and the value of q was found to be about unity. These results very strongly confirm the deductions of Elster and Geitel, and they lead to the following conclusion: The apparent conductivity of the air increases with the altitude. It is sensibly the same for both signs at the bottom of valleys, but on the summit of Mont Blanc it exhibits a nearly unipolar character. The variations of the ratio q, and of the electrical field appear to be so related as to conform to the theory of the ionization of the air by solar radiation, taking into account all the meteorological conditions which may affect the mobility of the ions and the intensity of radiation.

L. G. SCHULTZ.

ÜBER ELEKTRICITÄTSZERSTREUUNG BEI NEBELIGEM WETTER,[1]

[1] A. GOCKEL. Physikalische Zeitschrift, 4 Jahrgang No. 9, S. 267–270.

During September, 1902, observations were made on the Brienzer Rothorn, at an elevation of 2300 m, for the purpose of studying the electrical phenomena due to the presence of ions in fog or cloud masses. Measurements were made of the electrical conductivity with Elster and Geitel apparatus, the electrical potential gradient, the pressure, relative humidity and temperature of the air. The electrometer readings show that the potential variations were largely dependent upon the force of the winds and the movement of fog strata. On a fair day, with but little fog, an average gradient of about 300 V/M was observed; but as night approached and fog began to form it rose to 680 V/M. During days on which the mountain was more or less enveloped by fog, the gradient ranged from 500 to 750 V/M.

The coefficient q, of the electrical conductivity of the air was found to increase regularly on a fair day. Its extreme values on September 27th, were as follows: 6 to 7 a. m., 1.31; 10 to 11 a. m., 2.81; 1 to 2 p. m., 2.02; 2 to 3 p. m., 3.38; 4 to 5 p. m., 2.41; 5.30 to 6 p. m., 4.93; 8 to 9 p. m., 1.02. The presence of mists and fogs caused great variations in the value depending upon the position and state of the fog masses. Although the author does not so state, it is evident from the context that he assumes that fog masses surrounding mountain peaks are due to strong convection currents. A fog veil suspended over the station caused q to sink to 0.79; when the station was within a fog, q was always less than with a clear sky, and if the fog was in a nascent state, q was less than unity. In quiet, lowland fogs, q was generally found to be much greater than with clear sky. These results may be explained by the theory of ions thus: In the mountain regions rapid upward air currents carry an unusual quantity of negative ions which facilitate the dissipation of a positive charge and thus tend to make $q = 1$ or less. In the lowland fogs the negative ions are laden with moisture and practically inert while the positive ions having a smaller affinity for moisture remain active and dissipate the negative charge at about the normal rate. In case of supersaturation of the water vapor of the air, the positive ions may also become nuclei for the coudensa-

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tion of moisture and then q tends to equal unity. As fall and winter fogs usually occur with anticyclonic areas, the downward air currents reach the earth highly charged with positive ions from aloft, and they thus cause high potential gradients in such fogs and abnormally high values of q.

The author furthermore announces the following very important result of his investigations: During fair weather, at Freiburg, with a falling barometer and ascending air currents, positive charges are more rapidly dissipated than negative, so that the value of q becomes less than unity. This statement is indeed remarkable coming from central Switzerland where cyclonic conditions must invariably call forth föehn winds which must be highly charged with positive ions. It points out an interesting field for investigation.

The records of both Gockel and Le Cadet confirm the conclusion of the former that high values of q are less often due to an increase in the value of a_- than to a decrease in the value of $a+$, but the curves showing the diurnal variation of q on a fair day, as deduced by the two investigators are very dissimilar in that the maxima and the minima are almost exactly juxtaposed. Inasmuch as the observations were made during the same month and in the same portion of the earth it seems that there should be a better agreement.

L. G. SCHULTZ.

CHWOLSON'S LEHRBUCH DER PHYSIK.[1]

This is a German translation of the Russian edition of 1900, and will comprise four volumes. The first is on Mechanics, while the other three will contain Acoustics and Radiation, Heat, and Electricity and Magnetism.

The time has not yet come for the appearance of a text-book in which the laws of electricity will be treated as the foundation of all branches of physics, but modern tendencies already prefigure the day when the reviewer will be given the difficult task of passing judgment on such a work. Perhaps the future pioneer in this field, now at some college or "gymnasium," will win his early inspiration from the pages of the work before us. Certain it is, that Chwolson shows himself ready to leave the path of tradition, and take a step forward in the direction of presenting the facts and laws of physics in a more logical sequence and manner. Whether or not the attempt has been fully successful can only be proven when the work has been put to a practical test. As must be expected in all new departures, the volume before us contains certain defects that may impair its usefulness to some extent.

In spite of the author's assertion in the preface, the book can hardly be said to be suitable for pupils receiving their first instruction in physics. Not only is it too "advanced," but the illustrative examples used, especially in the introduction, although excellently selected, are taken freely from all branches of Physics, and hence almost unintelligible unless one has already had at least an elementary scientific training. For this reason we can not commend the idea of stating that no knowledge of mathematics beyond analytic geometry is required, and of inserting several pages on angular measurement and the principles of differential calculus. This seems especially unwise in view of

[1] *Lehrbuch der Physik* von O. D. CHWOLSON, Prof. ord. an der Kaiserl. Universität zu St. Petersburg. Erster Band. Uebersetzt von H. PFLAUM, Oberlehrer in Riga. Braunschweig, Vieweg und Sohn, 1902. Pp. XX + 791.

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the fact that integral expressions are repeatedly encountered in the course of the book, which could not possibly be understood without a sound knowledge of the calculus.

The distinguishing feature of the book arises from the author's determination to treat the science as "ein einheitliches Ganzes." While a branch of physics, Mechanics is infused with the same life-giving sap that permeates the whole tree. Analogies and even numerical examples from the laws of heat, light and electricity are freely used. The order of topics, beginning with gases and ending with the laws of solid bodies is strikingly original and perfectly logical, and in general consistently developed. It is, however, somewhat astonishing to find the atom everywhere regarded as the ultimate form of matter, no mention of the existence of the electron being made. Possibly this is being reserved for the volume on electricity; but the spirit that characterizes the work should have prompted the author at least to hint at the matter. In several minor particulars, exceptions might be taken to the arrangement of material. Thus, no good reason is evident why the two chapters on gravity should be separated by a chapter on the potential theory. The discussion of the pendulum is given partly under gravity, and partly under the measurement of time.

In the introduction, a keen and interesting discussion is given of the general problems of physics, the value of hypothesis, divisions of the science, etc. We are inclined to doubt the correctness of the statement that the science of photography is based upon physics alone, since the author's definition of physics here obviously does not include Chemistry.

The second part treats of the general laws of mechanics, and trespasses upon the field usually allotted to optics to the extent of dealing with wave motion, interference, etc. It is impossible in a brief space to give a fully adequate review of this, as indeed of the whole book. Some of the proofs appear rather indirect and unsatisfactory, but on the whole the subject is treated in a masterly way.

Part III, on physical measurements, is well introduced, though more might have been said about the discarding of decimals beyond those justified by the accuracy of the observations. The descriptions of the dividing engine and the balance are particularly good, but hardly enough space seems to have been devoted to the level and the vernier. It would have been better to reserve the description of the microscope, telescope and goniometer until the subject of the lenses had been taken up. Many unnecessary instrumental details are given, but on the whole this section ought to be valuable for reference.

The sections on the properties of gases, liquids and solids are of such a uniformly high order that any criticisms are necessarily on comparatively trivial matters. The simple automatic device for raising the mercury in a Sprengel pump is unnoticed. The paragraph on vortices is decidedly inadequate, and the first definition of colloids somewhat misleading, however correct it may be historically. A brief mention is made of quartz fibers, but nothing said about their uses. These omissions are all the more conspicuous in view of the completeness of most of the work.

The book is well printed, and the diagrams and cuts of instruments are excellent. It would have been more up-to-date in appearance, had photo-

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graphic reproductions been occasionally introduced, especially in illustrating capillarity, wave-motion, etc. The index is in general very satisfactory. At the end of most of the chapters a large list of references is appended; these ought to prove of great usefulness, though in some cases the most recent researches have not been included. It is to be regretted that a few of the chapters have been left without a statement of the literature.

As a text-book the work is heartily to be recommended to second or third year students of Physics, as well as to teachers. As a book of reference, it contains much that is valuable, in a more accessible form than it is to be found in the larger handbooks. We shall await with interest the appearance of the remaining volumes. W. G. CADY.

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SECOND REPORT ON MAGNETIC WORK IN MARYLAND.

BY L. A. BAUER.[1]

[Author's Abstract.]

This publication gives in detail and also summarizes all of the magnetic observations made in Maryland during the years 1896–1901, and describes the location of the stations. The observations were made with but few exceptions by the author, and the expense of the work was borne principally by the Maryland Geological Survey; though beginning with 1899, when the Division of Terrestrial Magnetism of the United States Coast and Geodetic Survey was formed, financial assistance was also rendered by the latter Survey. The instrumental outfit was loaned to the State by the Coast and Geodetic Survey.

The results are reduced to January 1, 1900, with the aid of a large number of repeat observations at the base station, Linden, Montgomery County, Maryland, from a discussion of which it was found that the average annual increase of west declination was 3′, the average annual decrease of dip was 1′.5, and the average annual decrease in horizontal intensity was 0.00007 c. g. s. units; these quantities apply, of course, only to the period of the magnetic survey. The reductions because of diurnal variation, annual variation, and disturbance variation, in the absence at that time of a magnetic observatory in close proximity to the area surveyed, had to be made with the aid of the observatory records obtained from 1889–1891, at the old and undisturbed site of the magnetic observatory which was then in operation at Washington under the auspices of the Naval observatory. For the elimination of disturbed values, use was also made of information received during the period of the survey from the Toronto magnetic observatory.

A discussion of the Linden series which embraced 22 observations of declination between July, 1896, and June, 1901, 21 values of dip between July, 1896, and July, 1900, and twenty-nine values of the horizontal intensity between July, 1896, and July, 1900, gave as the mean square error calculated from the formula,

$$\mu = \sqrt{\frac{[vv]}{n-1}}$$

in declination ± 1′.5, in dip ± 1′.17, and in horizontal intensity ± 0.00024 c. g. s. or ± $\frac{1}{800}$ H; the probable errors are, respectively, ±1′.01, ±0′.79, and ± 0.00016

[1] Special publication, Vol. V, pt. 1, Maryland Geological Survey, W. B. Clark, State Geologist. Baltimore, 1902. 98 pp. and four plates.

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or $\frac{1}{1040}$ *H*. In view of the fact that these errors represent the *total* error consisting of observation error and reduction error (diurnal variation, annual variation, and disturbance variation), it must be concluded that an accuracy sufficient for all purposes of a magnetic survey was reached. Some writers, and they are generally such who either have had little or no experience in field work and in the *utilization* of the results of field work, would give the impression that almost the same degree of accuracy must be striven for in field work as in observatory work. It takes no extensive field work to very soon convince one that if the declination and dip are obtained within 2′ and the horizontal intensity to $\frac{1}{1000}$ *H*, that these are the *highest* limits that need be striven for in field work, and any attempt made other than at base stations to exceed these limits which will result in decreasing thereby the *number* of observation points, is a grievous mistake. Frequently one may content himself with a less degree of accuracy; for the irregularities in distribution of the Earth's magnetism, as invariably revealed by increasing the number of stations, far exceed, in general, the errors of observation.

The quantities given above represent, furthermore, the limit of accuracy attainable with the instrumental outfit supplied to the State. But one of the needles of the dip circle proved satisfactory, and a double set with this needle was obtained at each station. The magnetometer had wooden bars, and it was shown that the deflection distances, owing to varying conditions of moisture, changed sufficiently to produce an error of about $\frac{1}{1000}$ *H*; moreover the prescribed deflection distances of thirty-five and forty-nine cms. gave too small deflection angles for the reading power of the horizontal circle. Since the author has taken charge of the magnetic survey of the United States, he has had this outfit overhauled; new needles were supplied to the dip circle, the wooden deflection bars of the magnetometer were replaced by brass ones, and the deflection distances were reduced to thirty and forty cms.

In conformity with the author's belief that a magnetic survey should not concern itself simply with the present magnetic distribution, but should also collect all previous results, he gives some additional secular variation data obtained since the publication of the First Report.

On three maps of Maryland (scale 1 : 1,125,000 or 20 miles to the inch) are given for January 1, 1900, respectively, the true isogonic lines, the true isoclinic lines and the true lines of horizontal intensity, as drawn, as best as possible, in conformity with the actual results; the points of observation are shown by dots. The three maps unite in exhibiting a fairly uniform distribution in southern, eastern, and extreme western part of Maryland; for this portion hardly any change was required in the preliminary lines given in the First Report and dependent upon a smaller number of stations. However, in the central portion of Maryland marked irregularities exist, and for this region the preliminary iso-magnetic lines published in the First Report have suffered considerable change, owing to the multiplicity of observations. The author, furthermore, expresses his belief that even the present lines represent only approximately the actual distribution.

A most interesting center of disturbance exists near Gaithersburg, about twenty miles northwest of Washington, where is situated one of the international observatories for the determination of the variation in latitude. This site having been proposed for the location of the principal magnetic observa-

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tory of the magnetic survey of the United States, it was decided to submit it first to a careful examination and so observations were made at a number of points in the vicinity. In a distance of about six miles, the declination varied from 0° 50′ W to 8° 24′ West, the dip from 71° 46′ to 70° 16′ and the horizontal intensity from 0.1880 to 0.2038. These results are exhibited in a separate map. An analysis of the forces producing the disturbances in this locality traces their source to parallel ridges running approximately in a northeast and southwest direction, and as this direction agrees with that of the serpentine beds containing magnetite, as mapped by the geologists, the inference would be that these beds, as in the northeastern part of Maryland, are the cause of the local disturbances.

The revealing of this region of disturbance emphasizes the need of careful surveys before deciding on the location of a standard magnetic observatory. The observatory was finally located in the southern part of Maryland—in the region of comparative uniform distribution (*Cf.* this volume of T. M. p. 13.)

Table XXI collects all of the results, and likewise gives the magnetic components, *X*, *Y*, and *Z*, and the total force *W*.

In conclusion, a preliminary attempt is made at an analysis of the terrestrial magnetic field in Maryland. The normal distribution is defined by a potential of simple harmonic type, the constants being determined from the observations by the method of least squares. The normal components *X*, *Y*, *Z* are thus not derived from independent, arbitrary formulæ as is frequently done, but are all derived from one physically interpretable function and, in consequence, refer to a common system of magnetic distribution. The publication of the final results and the discussion of the correlation of local magnetic disturbances and geological formations are deferred until the completion of the magnetic surveys of the surrounding States, now in progress.

The State of Maryland possesses now, on the average, one magnetic station to every one hundred square miles, Holland one to every forty square miles, and England one to every one hundred and thirty-nine square miles; Maryland thus ranks second in the matter of detailed magnetic surveys.

MAGNETIC OBSERVATIONS IN THE BAY OF TEPLITZ BY THE DUKE OF THE ABRUZZI NORTH POLAR EXPEDITION, 1899–1900.[1]

The observations were made by Captain Umberto Cagni, and reduced by Prof. Luigi Palazzo.

The magnetic instruments consisted of a Schneider unifilar magnetometer, and a Kew pattern dip circle. For the protection of the instruments during observation, a portable wooden house was provided. In the intervals between observations, the instruments had to be taken down, on account of the finely powdered snow which penetrated, in large quantities, even the knots and fissures of the wood.

[1] Osservazioni magnetiche eseguite dal COM TE. UMBERTO CAGNI nella Baia di Teplitz, calcolate dal PROF. LUIGI PALAZZO. Repr. from Scientific Results of the Duke of the Alruzzi Expedition, 1899–1900. (*Cf.* T. M. 189 VIII, p. 48.) Milan, 1903. 70 pp.

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On account of the limited scope of the expedition, the observations had to be confined to series of absolute measurements at the same station in August, 1899, and July, 1900. However, two 24-hour series of readings were made—one of declinations, at intervals of about 15 minutes, the other of inclination at intervals of half an hour. Both elements exhibited an extreme diurnal variation of over one degree — 1° 20′ for decl., 1° 29′ for dip.

Owing to the pronounced magnetic properties of the rocks, especially of the coast moraine, the station was located near the extreme edge of a bank of ice at least 8 meters thick, which fringed the coast. Thus the observations were probably influenced only by the presence of the island as a whole, and not by any accidental distribution of the rocks.

Azimuth observations in September, 1899, and June and July, 1900, show a change of 12′ 20″, due probably to a shifting of the ice supporting the station, by the extreme pressure of the drift ice during the winter.

Great difficulty was experienced in determining the magnetic meridian with the dip circle. Owing to the small horizontal directive force of the Earth's field, a motion in alidade of 10° produced no noticeable effect on the dip needle when the circle was nearly in the prime vertical. This results in an uncertainty of about 7′ in the inclination results. A still more serious difficulty was due to the construction of the dip circle, the cross pieces of the vertical circle, and the supporting pillars completely hiding one point of the needle in some positions. Previous to the measurements in 1900, this fault was remedied by changing the position of the circle, and altering the shape of the pillars.

The Schneider magnetometer proved a much more satisfactory instrument for use in high latitudes. All the instrumental constants were carefully determined, both before and after the expedition, by Prof. Pallazo.

The following table gives the mean of the results obtained, the position of the station being: Lat., 81° 47′ 25″ N., and Long., 58° 3′ 48″ East of Greenwich.

Epoch.	East. Decl.	Incl.	Hor. Int.	Vert. Int.	Tot. Int.
1899.7	21° 10′	83° 25′.0	0.06846	0.59319	0.59713
1900.6	21° 18′	83° 01′.2	0.06855	0.55990	0.56409

UNIVERSITY OF TEXAS, AUSTIN. J. M. KUEHNE.

M. POMORTSEFF'S "ABSOLUTE DETERMINATIONS OF THE ELEMENTS OF TERRESTRIAL MAGNETISM."[1]

(THEORY, METHODS OF OBSERVATION AND COMPUTATIONS.)

The activity of the Russians in magnetic work is again shown by the publication before us. The contents are as follows:

Chapter I: (1) Fundamental laws of magnetic phenomena, (2) Magnetic poles of very short magnets, and (3) The elements of terrestrial magnetism and their determination.

[1] Published in Russian at Katherinenburg, 1900. 8°. 124 pp.

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Chapter II: (1) Measurement of oscillations, (2) Measurement of force couples, and (3) Magnetic poles; influence of one magnet on another.

Chapter III: (1) Comparative determinations of the amount of the horizontal component of the force of terrestrial magnetism, (2) Absolute determinations of the amount of the horizontal component of the force of terrestrial magnetism, and (3) Continuous determinations, with formulæ for the force of terrestrial magnetism, and the introduction of corrected coefficients.

Chapter IV: (1) The determination of the magnetic inclination and declination, (2) The observation and computation of the horizontal component of the force of terrestrial magnetism, and (3) The precision with which the various elements should be determined.

Chapter V: (1) Mean values of the magnetic elements and their variations; cartographic data; brief sketch of the investigation of terrestrial magnetism, (2) Periodic measurements of the elements of terrestrial magnetism, (3) Magnetic perturbations, and (4) Distribution of the elements of terrestrial magnetism on the surface of the Earth.

U. S. C. AND G. S., WASHINGTON, D. C. W. C. HODGKINS.

ISOCLINIC AND ISOGONIC LINES IN MINDANAO ISLAND, PHILIPPINES.[1]

During the summer of 1902, Father M. S. Maso, S. J., Assistant Director of the Philippine Weather Bureau, had occasion to inspect the meteorological stations in the southern part of the archipelago, and took advantage of this trip to determine the magnetic elements at a number of places in the Island of Mindanao. From his results he was able to locate approximately the isogonic and isoclinic lines over the island for June, 1902. Both show a marked inflection toward the north, corresponding to the line of undoubted volcanic formations.

A number of the stations where Father Maso made observations had been occupied in 1888 or 1892,[2] and valuable data were thus obtained for determining the secular variation in that region. The earlier results were reduced to January 1, 1892, for use in the construction of iso-magnetic charts for that epoch. The results are given in a table, in which Father Maso has added for purposes of comparison the values of the magnetic elements at Zi-ka-wei, Hongkong, and Batavia, for the years 1892 and 1899.

From this table it is seen that the declination and horizontal intensity have been increasing throughout the island while the dip has decreased in a marked degree.

At Zamboango and Surigao observations were made also to study the diurnal variation. D. L. HAZARD.

U. S. COAST AND GEODETIC SURVEY.

[1] Isoclinic and Isogonic Lines in the Island of Mindanao. By FATHER MIGUEL SADERRA MASO, S. J., *Philippine Weather Bureau, Bulletin for October*, 1902.

[2] El Magnetismo Terrestre en Filipinos. By P. RICARDO CIRERA, S. J., Manila, 1893.

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MAGNETIC OBSERVATIONS AT ZI-KA-WEI, CHINA, IN 1900.[1]

This paper gives a statement of the progress of the magnetic work at the observatory at Zi-ka-wei during the year 1900.

Photographic registrations were obtained from a declinometer, a bifilar and a balance. Absolute observations were made at intervals, and in favorable weather daily observations were made on the sun for detecting and recording the appearances of solar spots.

After some preliminary remarks relating to the sensibility of the instruments, and to a comparison of various instruments and locations made use of in making absolute observations, the main portion of the paper is devoted to a discussion of the successive changes in the values of the magnetic elements, and of the changes in their diurnal variations. In addition, a complete record is kept of all disturbances, large and small, affecting D and H, and sometimes Z; and where the amount of a disturbance is measurable its value is given in minutes of arc or in C. G. S. units, and its direction is indicated by a + or — sign. This method of recording disturbances is very neat and clear. It was explained in a review of a portion of the previous annual report of this observatory (see T. M., Vol. VII, No. 3).

Three tables give the results of the absolute observations, and a fourth table gives the monthly means of the magnetogram readings.

Taking for the first of January the mean of all the hourly values for December aud January, the annual change is indicated as follows:

	Jan. 1, 1899	Jan. 1, 1900	Difference
	° ′	° ′	′
D	2 2043 W	2 2067 W	+0.24
I	45 4715	45 4824	+1.09
H	0.32815 c. g. s.	0.32837 c. g. s.	+0.00022 c. g. s.
X	0.32788 "	0.32810 "	+0.00022 "
—Y	0.01329 "	0.01343 "	+0.00004 "
Z	0.33729 "	0.33771 "	+0.00042 "
XW	0.47058 "	0.47103 "	+0.00045 "

The report does not make mention of any particularly interesting or important manifestation during the year. WM. F. WALLIS.

U. S. COAST AND GEODETIC SURVEY.

[1] Bulletin Mensuel de l'Observatoire Magnétique et Météorologique de Zi-ka-wei, Chine; tome XXVI, année 1900. Changhai, 1902.

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Stephen Joseph Perry.

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Terrestrial Magnetism

and

Atmospheric Electricity

VOLUME VIII SEPTEMBER, 1903 NUMBER 3

THE PHYSICAL DECOMPOSITION OF THE EARTH'S PERMANENT MAGNETIC FIELD.[1] No. III.

a. The Earth's Total Magnetic Energy.
b. The Seat of the Principal Cause of the Secular Variation.
c. On the Improvement of the Gaussian Theory.

By L. A. Bauer,

Lecturer in Terrestrial Magnetism, Johns Hopkins University; Chief of Division of Terrestrial Magnetism, U. S. Coast and Geodetic Survey.

a. THE EARTH'S TOTAL MAGNETIC ENERGY.[2]

The purpose of this paper is to determine wether the accumulation of magnetic data is already sufficient to ascertain if the total magnetic energy of the Earth's so-called "permanent" magnetic field has remained constant for the period of the accumulated data, or has been subject to a secular variation, as in the case of all the magnetic elements. A secular variation of the magnetic elements may result from: (a) secular changes in the direction or directions of magnetization of the Earth; (b) secular changes in the intensity of magnetization of the Earth, and (c) from operation of both causes (a) and (b). From previous investigations of the secular variation, cause (a) appeared to me the predominant factor.

[1] For No. I of these researches, see this Journal, Vol. IV, 1899, p. 35, and for No. II, see Vol. VI, 1901, p. 13.

[2] Presented, in abstract, for the author, by Professor A. Schuster, before Sec. A of the British Association for the Advancement of Science, Sept., 1903.

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The expression to be established, defining what I term the "Earth's total magnetic energy" is independent of the *directions* of the magnetization of the Earth, and hence should remain constant for all time, if the secular variations be due solely to cause (a). If, however, the values of the magnetic energy for two periods, separated by a suitable interval, differ by an amount which can not be accounted for by uncertainties in the values themselves, arising from inadequacy of the data or from imperfections in the method of calculation, then we shall have evidence of great importance to theories of the Earth's magnetism, viz: that the Earth's intensity of magnetization, owing to some cause, is subject to secular change. And if so, it is very important to know whether the Earth's magnetic energy is increasing or decreasing. Manifestly, therefore, the present investigation is one well worth our attention, whatever the outcome may be, even though it may but lead to the conclusion that our present knowledge of the actual distribution of the Earth's magnetism, in spite of the extensive data already accumulated, is in reality a very unsatisfactory one.

How are we to define the "Earth's total magnetic energy"?

The potential of the Earth's total magnetism can be expressed, with great approximation, as Gauss first showed, in solid spherical harmonics to terms of the fourth order inclusive; the addition of terms of the fifth and sixth order, as revealed by the investigations of Adams, Fritsche, and Schmidt effect some improvement. I have shown in my previous papers, that the spherical harmonic of the first order can be physically interpreted as arising from a homogeneous magnetization of the Earth about a diameter inclined to the axis of rotation;[1] the inclination of this axis is about 11.°4, and this first harmonic term represents, approximately, $\frac{7}{8}$ of the Earth's total magnetization. The well-known expression of the "Earth's magnetic moment," as introduced by Gauss, represents only that portion of the total magnetization which arises from the first term, *i. e.*, from the homogeneous magnetization. Now, if we tabulate all the values of the magnetic moment obtained thus far by the various computers of the Gaussian potential, whose detailed results will be found given in a subsequent table, it would appear as though the magnetic moment has suffered a perceptible diminution—1.6%—during the period 1838–1884.

[1] I have recently found that I was anticipated in this interpretation of the first harmonic by Professor J. D. EVERETT, in his "Units and Physical Constants." London. Macmillan & Co., 1879, p. 125, paragraph 151.

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VALUES OF THE EARTH'S MAGNETIC MOMENT IN C. G. S. UNITS.

No.	Computer of Potential.	Epoch.	Value.	
1	Erman-Petersen	1829	0.32690 R^3	
2	Adams	1842.5	32820	Mean 1, 2 & 3, 1838, 0.32812 R^3
3	Fritsche	1842.5	32927	4, 5, 6 & 7, 1884, 32288
4	Adams	1880	32344	
5	Fritsche	1885	32272	Change in 46 years, 0.00524 R^3
6	Neumayer-Petersen . .	1885	32237	Hence, 1.6%
7	Schmidt	1885	32298	

Since the quotient of the magnetic moment by the Earth's total volume, represents the intensity of magnetization per unit of volume, the conclusion would, therefore, apparently be that the intensity has decreased at an alarming rate in forty-six years. The same conclusion would be reached with regard to the Earth's magnetic energy, since the latter, for the homogeneous magnetization portion, can be expressed in terms of the magnetic moment.

The question arises: Is this comparatively great loss in the magnetic moment during an interval of but half a century, to be ascribed to insufficiency or imperfection of data for the periods for which the calculations are made, or, if we were to take into account the remaining portion of the Earth's magnetization, represented by the second, third, and fourth harmonics, would the loss of energy of the first term be compensated for, wholly or partially, by a possible gain in energy of the remaining terms, or would the remaining terms likewise exhibit a decrease in energy?

To answer these questions, I shall introduce the well-known function in physics, expressing the energy of a distribution of forces in terms of the field, and I shall designate it by the letter *W*, the initial letter of "work" or the German "werk."[1]

It is defined as the sum total of the magnetic energy of all the elements of volume in the space bounded by the Earth's surface and a sphere of infinite radius, *i. e.*, of radius large enough that the energy of the excluded portion may be neglected,[2] as due to the field of force arising from the Earth's magnetization. The magnetic energy of an element of volume in a field of force of the kind

[1] The Earth's total potential is not used for these investigations, as the integral of this potential for any closed space is zero for every period, just as the Earth's total quantity of magnetism is supposed always zero.

[2] At a height above the Earth, fifteen times that of the Earth's radius, or about one-fourth the distance to the Moon, the Earth's total magnetic force will have dwindled to a quantity equal to the error of observation of the best-class instruments used in making field observations of the magnetic elements.

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here discussed, may be taken as proportional to the square of the force of the field at the point considered; it represents the amount of work done to bring, for example, a unit magnetic pole repelled by the field from an infinite distance to the point. The factor of proportionality μ, is the inductivity or the magnetic permeability of the medium; for the space regarded we may take this, I presume, as uniform, and set it equal to unity. Were the portion of space occupied by the Earth itself, also embraced, then μ could no longer be regarded as uniform. Owing to our ignorance of the precise composition of the Earth's interior, the law of variation of μ is not known, and there would, hence, result expressions in the integral, representing W, which could not be evaluated. *W has, therefore, been confined to the space outside.*

It is, doubtless, unnecessary to remark that the magnetic energy of any element of volume, outside the Earth, due to fields giving rise to periodic or non-periodic magnetic variations, *e. g.*, the diurnal variation, magnetic storms, etc., is not here considered, since in the field of force, usually referred to as the "permanent or quasi-permanent field," all variations at any particular time are supposed eliminated.

The mathematical expression for the energy of a field of force obeying Newton's law, as will be found from various text-books,[1] is:

$$W = \frac{1}{8\pi} \int \mu F^2 \, d\tau \quad . \qquad (1)$$

μ = magnetic permeability at any point in space; F = the total field intensity at any point, x, y, z; $d\tau = dx\, dy\, dz$ = element of volume.

Confining the integral to the space outside of the Earth, μ will be regarded, as already stated, constant and set equal to unity. Introducing the polar co-ordinates, r (radius vector), u (co-latitude), and λ (the longitude counted positive to the eastward), and letting X, be the component directed positive to the north, Y, the component directed positive to the east, and Z, the component, directed positive downwards (towards nadir), and if R be the Earth's mean radius we have:

$$W = \frac{1}{8\pi} \int_0^{2\pi} \int_0^{\pi} \int_R^{\infty} (X^2 + Y^2 + Z^2)\, r^2 \sin u \, d\lambda \, du \, dr \quad . \qquad (2)$$

In this equation, as in all subsequent ones, r is supposed counted positive outwards from the center of the Earth.

[1] An admirable work for American students, is: WEBSTER'S Electricity and Magnetism. Macmillan & Co. 1897.

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If V be the magnetic potential at any point in the external space, then

$$X = -\frac{\partial V}{\partial x} \quad , \quad Y = -\frac{\partial V}{\partial y} \text{ and } Z = -\frac{\partial V}{\partial z} \quad .$$

Substituting in equation (2), applying Green's theorem to the right hand member, and remembering that for the space considered, $\Delta V = 0$, in accordance with Laplace's equation[1] and also that both V and Z vanish for $r = \infty$, we obtain as another expression for the energy:

$$W = -\frac{R^2}{8\pi} \int_0^{2\pi} \int_0^{\pi} V Z \sin u \, d\lambda \, du \quad . \tag{3}$$

This integral, as the one in (2), is positive, since, in accordance with the notation used in this paper, V and Z are, at every point of opposite sign.

Substituting the dimensions of field intensity and of potential in equation (2) or (3), it will be found that W has correctly the dimensions of energy or work, $[M L^2 T^{-2} \cdot]$

The Earth's total magnetic energy can thus be calculated in two ways:

1. By obtaining the sum total of the products of the square of the total intensity of the field into the element of volume, at every point in the entire space outside the Earth, and dividing the sum by 8π.

2. By obtaining the sum total of the products of the magnetic potential and the vertical component of the field intensity into the element of surface, for the entire surface of the Earth, and dividing the sum by 8π.

First Method of Computing the Earth's Magnetic Energy.

We must know the magnetic potential V at every point for the space considered. Following the notation as already used in Nos. I and II of these researches,[2] which is the same as that adopted by Schmidt, we have:

$$X = \frac{1}{r} \cdot \frac{\partial V}{\partial u} \quad , \quad Y = -\frac{1}{r \sin u} \cdot \frac{\partial V}{\partial \lambda} \text{ and } Z = \frac{\partial V}{\partial r} \quad . \tag{4}$$

[1] $\Delta V = 0$, is also the condition that W shall have a minimum value for the space considered.

[2] In No. I, p. 38, equation (2) should read

$$X = +\frac{1}{R} \frac{\partial V}{\partial u} \quad .$$

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$F^2 = X^2 + Y^2 + Z^2$ is then known at every point, and the integrations are easily effected.

The potential at any point in the space considered, due to a magnetic system inside the Earth, may be expressed as follows:

$$V = \frac{R^3}{r^2} \cdot P_1 + \frac{R^4}{r^3} \cdot P_2 + \frac{R^5}{r^4} \cdot P_3 + \ldots \qquad (5)$$

P_1, P_2, P_3, . . . are, respectively, surface spherical harmonics of 1st, 2d, 3d, and etc., orders.

For example, $P_1 = [g_{10} \cos u + (g_{11} \cos \lambda + h_{11} \sin \lambda) \sin u]$.

$$X = \frac{R^3}{r^3}\left(\frac{\partial P_1}{\partial u} + \ldots\right), \quad Y = -\frac{1}{\sin u} \cdot \frac{R^3}{r^3}\left(\frac{\partial P_1}{\partial \lambda} + \ldots\right),$$

$$\text{and } Z = -\frac{R^3}{r^3}\left(2 P_1 + 3 \frac{R}{r} \cdot P_2 + 4 \frac{R^2}{r^2} \cdot P_3 + \ldots\right). \qquad (6)$$

As the expression W will contain the squares of the Gaussian coefficients (the g's and h's), I shall employ entirely subscripts to designate the coefficients of the various terms, and for convenience in writing and printing, omit furthermore the commas between the subscripts. The g's and h's, of which the collective number is 24 for terms to the fourth order, are coefficients determined for any particular period from the known values X and Y and Z.[1]

The values of g and h as obtained by various computers of the Earth's magnetic potential, are given later.

Forming the quantity $X^2 + Y^2 + Z^2$, omitting at once terms which by well-known formulæ in integral calculus, or in spherical harmonics, are known to vanish when integrated over the entire Earth,[2] and performing the various integrations we have:

$$\left.\begin{aligned} W &= W_1 + W_2 + W_3 + W_4 + \ldots . \\ &= R^3 \Big\{ \tfrac{1}{3}(g_{10}^2 + g_{11}^2 + h_{11}^2) + \tfrac{1}{5}\left[\tfrac{3}{8} g_{20}^2 + \tfrac{1}{2}(g_{21}^2 + h_{21}^2) \right. \\ &\qquad \left. + 2(g_{22}^2 + h_{22}^2)\right] \\ &\quad + \tfrac{1}{3^5}\left[\tfrac{5}{8} g_{30}^2 + \tfrac{10}{16}(g_{31}^2 + h_{31}^2) + \tfrac{5}{8}(g_{32}^2 h_{32}^2) + 16(g_{33}^2 + h_{33}^2)\right] \\ &\quad + \tfrac{1}{3^8}\left[\tfrac{35}{128} g_{40}^2 + \tfrac{4}{7}(g_{41}^2 + h_{41}^2) + \tfrac{5}{7}(g_{42}^2 + h_{42}^2) + 4(g_{43}^2 + h_{43}^2)\right. \\ &\qquad \left. + 32(g_{44}^2 + h_{44}^2)\right] + \ldots . \Big\} . \end{aligned}\right\} \qquad (7)$$

[1] Like the magnetic elements, the coefficients are subject to a secular variation, and presumably, in accordance with the same law as applies to the elements themselves. Thus, since the secular variation investigations of the observed elements show that for an interval of a century or more the variation can be expressed in the form of a Bessel series, of which the first sine term represents a very close approximation, we may expect that the first approximation to the law of secular variation of the Gaussian coefficients is also that of a simple sine function of the element t, time.

[2] Thus, for example, it can be shown that only terms involving the squares of the individual coefficients to contribute to W, all the product terms disappearing when integrated over the entire surface.

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Second Method of Computing the Earth's Magnetic Energy.

Substituting the values of V and Z in equation (3), and omitting all products of the spherical harmonic terms, which when integrated over the entire Earth's surface are known to vanish, in accordance with well-known theorems in spherical harmonics, we have:

$$W = \frac{R^3}{8\pi} \int_0^{2\pi} \int_0^{\pi} (2 P_1^2 + 3 P_2^2 + 4 P_3^2 + - -) \sin u \, d\lambda \, du \quad . \quad (8)$$

This is a decidedly simpler expression than the one from the first method; it was found to lead to the same result as already given, and thus equation (7) was checked.

With the aid of Schmidt's "R" functions, which, to avoid confusion with R, the Earth's mean radius, I shall designate by "S," and which are equal to the P functions multiplied by a factor "s," determined so that:

$$\int_0^{2\pi} \int_0^{\pi} (S^2 = s^2 P^2) \cos^2 m\lambda \text{ (or } \sin^2 m\lambda) \sin u \, d\lambda \, du = 4\pi \quad ,$$

the expression for W can be put in its most elegant form.

Instead of the g and h coefficients of Gauss, we shall now have the γ and η coefficients of Schmidt, the two sets of coefficients being related thus:

$$s_{n\,m} \cdot \gamma_{n\,m} = g_{n\,m} \quad , \quad s_{n\,m} \cdot \eta_{n\,m} = h_{n\,m} \quad .$$

The values of $s_{n\,m}$ are given later. Continuing, we have as our final expression:

$$W = R^3 [(\gamma_{10}^2 + \gamma_{11}^2 + \eta_{11}^2) + \tfrac{3}{2} (\gamma_{20}^2 + \gamma_{21}^2 + \eta_{21}^2 + \gamma_{22}^2 + \eta_{22}^2) + 2 (\gamma_{30}^2 + \gamma_{31}^2 + \eta_{31}^2 + \gamma_{32}^2 + \eta_{32}^2 + \gamma_{33}^2 + \eta_{33}^2) + \tfrac{5}{2} (\gamma_{40}^2 + \gamma_{41}^2 + \eta_{41}^2 + \gamma_{42}^2 + \eta_{42}^2 + \gamma_{43}^2 + \eta_{43}^2 + \gamma_{44}^2 + \eta_{44}^2) + \ldots] \quad . \quad (9)$$

I have made independent computations, using both formulæ (7) and (9), getting identical results, and have thus checked the correctness of these two formulæ.

Table II gives a tabulation of the Gaussian coefficients as obtained by various computers for various epochs. The references to the publications from which the figures were taken are appended. The figures in column 10 have been obtained from those in column 13, by multiplying by the conversion factor, as given in Table I. It should be noted that the signs in Table II, in conformity with the

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notation used by Schmidt and myself, are the reverse of those given by the computers who followed Gauss's notation. Strictly speaking it is not quite correct, because of the greatly varying magnitudes of the P coefficients, as was first pointed out by Schmidt, to express all the g's and h's to the same decimal; their relative importance can not always be gauged by their magnitudes. In this respect the coefficients introduced by Schmidt, and as given in Table III, have a decided advantage.

Columns 1 to 5 inclusive, and 11 and 12, give the values of the coefficients, concluding the harmonic series with terms of the fourth order, whereas columns 6–10 and 13 give the results with terms of the fifth and sixth order included. The effect on the coefficients, resulting from extension of the series, can thus be seen by comparing the respective columns.

The results from the potential computation of Quintus Icilius for 1880, are too defective to warrant including them in the table, and have accordingly, been omitted.

Column 14 gives the coefficients for the small external potential deduced by Schmidt for 1885, and 15, the same, as deduced by Fritsche from the combined results for 1842 and 1885.

TABLE I. FACTORS FOR CONVERTING SCHMIDT'S COEFFICIENTS INTO GAUSSIAN COEFFICIENTS.

	Factor	Logarithm		Factor	Logarithm		Factor	Logarithm		Factor	Logarithm
S_{00}	1	0.00000	S_{30}	$\frac{5}{2}\sqrt{7}$	0.82049	S_{50}	$\frac{63}{8}\sqrt{11}$	1.41695	S_{60}	$\frac{231}{16}\sqrt{13}$	1.71646
S_{10}	$\sqrt{3}$	0.23856	S_{31}	$\frac{5}{3}\sqrt{42}$	0.90853	S_{51}	$\frac{21}{8}\sqrt{165}$	1.52787	S_{61}	$\frac{33}{8}\sqrt{273}$	1.83351
S_{11}	$\sqrt{3}$	0.23856	S_{32}	$\frac{1}{2}\sqrt{105}$	0.70956	S_{52}	$\frac{3}{4}\sqrt{1155}$	1.40635	S_{62}	$\frac{33}{32}\sqrt{2730}$	1.73145
S_{20}	$\frac{3}{2}\sqrt{5}$	0.52558	S_{33}	$\frac{1}{4}\sqrt{70}$	0.32049	S_{53}	$\frac{9}{16}\sqrt{770}$	1.19337	S_{63}	$\frac{11}{16}\sqrt{2730}$	1.55535
S_{21}	$\sqrt{15}$	0.58805	S_{40}	$\frac{105}{8}$	1.11810	S_{54}	$\frac{3}{8}\sqrt{385}$	0.86676	S_{64}	$\frac{33}{16}\sqrt{91}$	1.29391
S_{22}	$\frac{1}{2}\sqrt{15}$	0.28702	S_{41}	$\frac{21}{4}\sqrt{10}$	1.22016	S_{55}	$\frac{3}{16}\sqrt{154}$	0.36676	S_{65}	$\frac{3}{16}\sqrt{2002}$	0.92373
			S_{42}	$\frac{21}{4}\sqrt{5}$	1.06964				S_{66}	$\frac{1}{32}\sqrt{6006}$	0.38414
			S_{43}	$\frac{3}{4}\sqrt{70}$	0.79761						
			S_{44}	$\frac{3}{8}\sqrt{35}$	0.34607						

With the aid of the figures in Tables I and II, we can now compute the magnetic energy. To show the effect of the various terms, the following specimen, using formula (9) is given.

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TABLE II. Values of the Gaussian Coefficients, in units of the fifth decimal.

	1. Er.-Pet. 1829	2. Gauss 1830	3. Adams 1840–5	4. Adams 1880	5. Neu.-Pet 1885	6. Adams 1840–5	7. Fritsche 1840–5	8. Adams 1880	9. Fritsche 1885	10. Schmidt 1885
g_{10}	— 32007	— 32348	— 32173	— 31611	— 31572	— 32187	— 32271	— 31684	— 31635	— 31733
g_{11}	— 2835	— 3111	— 2833	— 2470	— 2481	— 2778	— 2751	— 2427	— 2414	— 2356
h_{11}	+ 6011	+ 6246	+ 5820	+ 6071	+ 6026	+ 5783	+ 5931	+ 6030	+ 5914	+ 5984
g_{20}	— 121	+ 771	+ 57	— 749	— 791	+ 127	+ 28	— 731	— 526	— 785
g_{21}	+ 4454	+ 5064	+ 4887	+ 5078	+ 4980	+ 4913	+ 4746	+ 5136	+ 4962	+ 4895
h_{21}	— 72	+ 211	— 194	— 1299	— 1300	— 181	— 245	— 1293	— 1307	— 1243
g_{22}	— 125	— 17	+ 38	+ 532	+ 567	+ 35	+ 66	+ 530	+ 589	+ 587
h_{22}	+ 1264	+ 1363	+ 1174	+ 1287	+ 1260	+ 1165	+ 1148	+ 1289	+ 1230	+ 1294
g_{30}	+ 1876	+ 659	+ 2448	+ 2856	+ 2436	+ 2416	+ 2148	+ 2680	+ 2556	+ 2342
g_{31}	— 2986	— 4296	— 3366	— 4383	— 3956	— 3130	— 3362	— 4197	— 3807	— 3775
h_{31}	— 1645	— 1670	— 1213	— 573	— 738	— 1372	— 1263	— 748	— 1005	— 907
g_{32}	+ 3073	+ 2558	+ 2769	+ 2793	+ 2786	+ 2802	+ 2660	+ 2822	+ 2667	+ 2767
h_{32}	+ 621	+ 796	+ 408	— 36	+ 44	+ 409	+ 400	— 40	— 13	+ 51
g_{33}	+ 127	— 49	+ 207	+ 289	+ 327	+ 207	+ 189	+ 289	+ 368	+ 316
h_{33}	+ 725	+ 655	+ 678	+ 493	+ 549	+ 678	+ 699	+ 493	+ 555	+ 540
g_{40}	+ 2738	+ 3804	+ 2909	+ 3223	+ 3440	+ 3105	+ 2944	+ 3375	+ 4014	+ 3478
g_{41}	+ 3840	+ 5329	+ 3183	+ 3461	+ 3060	+ 3286	+ 3426	+ 3683	+ 3104	+ 2839
h_{41}	+ 320	— 2240	+ 498	+ 1038	+ 1188	+ 551	+ 541	+ 1062	+ 1381	+ 1567
g_{42}	+ 1559	+ 1600	+ 1557	+ 1949	+ 1975	+ 1528	+ 1647	+ 1933	+ 2128	+ 2019
h_{42}	— 1085	— 1488	— 996	— 539	— 715	— 989	— 956	— 522	— 652	— 669
g_{43}	— 671	— 691	— 352	— 557	— 684	— 353	— 304	— 559	— 601	— 646
h_{43}	— 301	+ 6	— 391	— 432	— 512	— 391	— 429	— 433	— 525	— 471
g_{44}	— 90	+ 144	— 14	+ 108	+ 85	— 14	000	+ 108	+ 63	+ 118
h_{44}	— 111	— 111	— 101	— 94	— 97	— 100	— 103	— 94	— 103	— 55
g_{50}						— 237	— 183	— 1290	— 1208	— 1332
g_{51}						+ 3617	+ 3623	+ 2841	+ 3028	+ 4013
h_{51}						— 2440	— 2312	— 2680	— 3647	— 2731
g_{52}						+ 3049	+ 2942	+ 2684	+ 1961	+ 2192
h_{52}						+ 116	+ 293	— 297	— 227	— 255
g_{53}						+ 108	+ 38	+ 55	+ 272	+ 78
h_{53}						— 44	— 193	— 131	+ 49	+ 109
g_{54}						— 125	— 109	— 20	— 134	— 15
h_{54}						— 83	— 142	— 115	— 132	— 169
g_{55}						+ 70	+ 76	+ 66	+ 64	
h_{55}						+ 40	+ 42	+ 19	+ 43	
g_{60}						+ 1384	+ 313	+ 364	+ 1285	+ 312
g_{61}						+ 1256	+ 1153	+ 2724	+ 1686	+ 409
h_{61}						+ 644	+ 389	+ 284	+ 1796	+ 1704
g_{62}						— 1293	— 1088	— 731	— 572	— 808
h_{62}						+ 320	+ 293	+ 824	+ 1122	+ 970
g_{63}						— 1114	— 1411	— 1723	— 1502	— 1616
h_{63}						— 572	— 522	— 528	— 757	— 647
g_{64}						— 298	— 191	— 354	— 200	— 118
h_{64}						— 279	— 127	— 184	— 346	— 138

TABLE III. Values of Schmidt's Coefficients, in units of the fifth decimal.

	11. Neu-Pet. 1885	12. Schmidt 1885	13. Schmidt 1885	14. V e S. 1885	15. V e F'42-'85
γ_{10}	—18228	—18243	—18321	—107	—137
γ_{11}	— 1433	— 1471	— 1361	+139	+ 40
η_{11}	+ 3479	+ 3496	+ 3455	— 2	+ 22
γ_{20}	— 236	— 243	— 234	+ 1	— 28
γ_{21}	+ 1286	+ 1267	+ 1264	— 32	— 13
η_{21}	— 336	— 340	— 321	+ 4	+ 7
γ_{22}	+ 293	+ 300	+ 303	— 28	— 12
η_{22}	+ 651	+ 653	+ 668	+ 2	— 32
γ_{30}	+ 368	+ 405	+ 354	0	— 15
γ_{31}	— 488	— 538	— 466	+ 14	+ 41
η_{31}	— 91	— 57	— 112	— 0	+ 25
γ_{32}	+ 544	+ 527	+ 540	— 14	— 34
η_{32}	+ 9	+ 8	+ 10	— 5	+ 9
γ_{33}	+ 156	+ 155	+ 151	+ 6	— 14
η_{33}	+ 263	+ 263	+ 258	— 21	— 18
γ_{40}	+ 262	+ 259	+ 265	+ 12	— 8
γ_{41}	+ 184	+ 158	+ 171	— 14	— 20
η_{41}	+ 72	+ 68	— 94	— 3	— 7
γ_{42}	+ 168	+ 172	+ 172	+ 15	+ 14
η_{42}	— 61	— 63	— 57	+ 19	+ 11
γ_{43}	— 109	— 106	— 103	+ 1	— 4
η_{43}	— 82	— 79	— 75	+ 14	+ 15
γ_{44}	+ 38	+ 40	+ 53	+ 18	+ 14
η_{44}	— 44	— 42	— 25	— 2	— 3
γ_{50}			— 51	— 2	— 22
γ_{51}			+ 119	+ 21	+ 25
η_{51}			— 81	+ 6	+ 1
γ_{52}			+ 86	+ 21	+ 6
η_{52}			— 10	+ 7	+ 3
γ_{53}			+ 5	— 0	+ 1
η_{53}			+ 7	— 9	— 8
γ_{54}			— 2	— 20	— 2
η_{54}			— 23	— 4	— 5
γ_{55}					— 9
η_{55}					— 3
γ_{60}			+ 6	+ 0	+ 6
γ_{61}			+ 6	— 16	+ 5
η_{61}			+ 25	— 5	+ 6
γ_{62}			— 15	+ 11	+ 6
η_{62}			+ 18	+ 8	— 6
γ_{63}			— 45	+ 19	+ 2
η_{63}			— 18	+ 10	+ 5
γ_{64}			— 6	+ 16	— 2
η_{64}			— 7	+ 25	— 3

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TABLE IV. Specimen of calculation of $\frac{W}{R^3}$.

		11. Neu.-Pet. 1885	12. Schmidt 1885	13. Schmidt 1885			11. Neu.-Pet. 1885	12. Schmidt 1885	13. Schmidt 1885
2/2	γ_{10}^2	0.033226	0·033281	0·033566	3/2	γ_{20}^2	.000009	.000009	.000008
	γ_{11}^2	205	216	185		γ_{21}^2	248	241	240
	η_{11}^2	1210	1222	1194		η_{21}^2	16	18	15
I		.034641	34719	34945		γ_{22}^2	13	14	14
						η_{22}^2	63	64	67
					II		349	346	344
4/2	γ_{30}^2	28	33	25	5/2	γ_{40}^2	18	17	18
	γ_{31}^2	·48	58	43		γ_{41}^2	8	6	7
	η_{31}^2	1	1	3		η_{41}^2	2	1	2
	γ_{32}^2	59	56	58		γ_{42}^2	8	7	7
	η_{32}^2	0	0	·0		η_{42}^2	1	1	1
	γ_{33}^2	5	5	5		γ_{43}^2	2	3	3
	η_{33}^2	14	14	13		η_{43}^2	2	2	1
III		155	167	147		γ_{44}^2	0	0	1
						η_{44}^2	0	0	0
					IV		41	37	40
II + III + IV,		.000545	.000550	.000531					
Total, ...		.035186	.035269	.035476					

TABLE V. VALUES OF THE EARTH'S TOTAL MAGNETIC ENERGY.

[The tabular numbers are to be multiplied by the cube of the Earth's mean radius.]

No.	Computer of Potential	Epoch	I	II	III	IV	II + III + IV	Total
1	Erman-Petersen .	1829	.03562	.00026	.00015	.00004	.00045	.03607
3 and 6	Adams . .	1842.5	3590	29	15	3	47	3637
4	Fritsche . . .	1842.5	3614	28	14	3	45	3659
8	Adams . . .	1880	3481	36	17	4	57	3538
9	Fritsche . . .	1885	3472	34	15	4	53	3525
5 and 11	Neumayer Petersen .	1885	3464	35	16	4	55	3519
10 and 13	Schmidt . .	1885	3494	34	15	4	53	3548
	Mean of first three . . .	1838	.03589				·00046	·03635
	Mean of last four	1884	3478				54	3532
	Change in . .	46 years	—.00111				+·00008	—·00103

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Table V, giving the values of the Earth's total magnetic energy, will be readily understood; thus, for 1829, the energy from the first harmonic is 0.03562 R^3; from the second, 0.00026 R^3; from the third, 0.00015 R^3, from the fourth, 0.00004 R^3, the total of the four terms being 0.03607 R^3. The results from the Gaussian computation are omitted, as it was not deemed fair to Gauss to present his results—preliminary, as he desired them considered—alongside of those dependent upon superior material.

A close scrutiny of the material and method of computation, employed by the various computers of the Gaussian coefficients, decided me to give equal weight in the combination of the results for the magnetic energy. Thus we have:

Earth's Total Magnetic Energy

1838, ... 0.03635 R^3

1884, ... 0.03532 R^3

Loss in 46 years, ... 0.00103 R^3 or 2.88 per cent, or about $\frac{1}{35}$ part.

This loss is almost entirely in the term representing the portion of the Earth's magnetism to be referred to a homogeneous magnetism, it amounting to 3.15 per cent.

The result is so startling—if it be true, and the loss were to continue at the same rate as during the period 1838–1884, the Earth would lose its entire magnetic energy in about 1,600 years—that extreme caution should be used before coming to a definite conclusion.

Glancing over the results in the last column of Table V, it will be seen that the various values of the magnetic energy for the same epoch and dependent upon practically the same material, differ on the average, about 0.3 per cent, or about $\frac{1}{10}$ of the observed decrease in energy between 1838–1884.

The question as to the effect on the value of the energy due to the completeness or incompleteness of the material employed, is somewhat difficult to determine, as modern constructors of magnetic charts, have not published in detail the material on which the charts are based. Some evidence as to the amount of the effect may be gathered by comparing the 1829 and 1842 values. In both cases the material used extended over a considerable period before and after the epoch selected, in the latter one, however, the material was somewhat more extensive than for the former. Referring the 1829 value to 1842.5, using the annual rate of decrease

$$\frac{.00103}{46} R^3 = 0.0000224\, R^3,$$

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we obtain for the magnetic energy .03577 R^3, against the mean of the two 1842 results, 0.03648 R^3, hence a difference of 0.00071 R^3 or 1.97 per cent. Whether the difference in the completeness of the material between the 1842 charts, and the 1880 or 1885 charts, is as pronounced as for the comparison just made can not be said off-hand. In certain regions of the Earth, there has been either no gain at all, or very little in the material since the Sabine charts of 1840–1845.

While then the observed decrease in magnetic energy in the interval of 46 years, between 1838 and 1884, is larger than can apparently be ascribed to method of computation of the Gaussian coefficients, or to the character of the material employed, it will be safest, at the present stage, until other related investigations have been completed, to leave open the inquiry whether the Earth's total magnetic energy remains constant, or is suffering an increase or a decrease with the lapse of time.

This investigation, however, most emphatically indicates the great need of a fresh potential computation as dependent upon strictly homogeneous data, distributed fairly uniformly, say between the parallels 60° North and 60° South, the entire data having been obtained within a sufficiently brief interval, to eliminate the effect of secular variation. Thus, in view of the fact, that for very large areas of the globe, as already stated, practically no additional material has been obtained since the epoch for which Sabine drew his magnetic charts of 1840–1845, upon which the results given above for 1840–1845 depend, it may easily happen that the potential expression for 1885 may not represent any very great absolute improvement over that for 1840–1845, no matter how carefully and scientifically the computer may have performed his task. I take this occasion, also, to emphasize the need of complete publication of the original material on which a magnetic chart or a potential computation depends, so that an outsider may obtain some idea as to the amount of reliance to be put upon a chart or upon the results of a potential computation, based thereon.

For the sake of comparison, it may be of interest to give the value of the magnetic energy for the external potential determined by Schmidt and Fritsche. Supposing an internal system, producing equivalent effects on the Earth's surface, to those produced by the external potential, the magnetic energy of this portion would be 0.00000449 R^3, or 0.0125 per cent of the internal portion above given.

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Uses of the Energy Function.

Could we assume that the Earth's total magnetic energy remains constant, either in its entirety, or only as far as some of its constituents are concerned, we should have a valuable aid in the energy function for expressing the Gaussian coefficients as functions of the time. In a paper presented to the American Association for the Advancement of Science, in 1894 (See *Proc.* Vol. XLIII, 1894), I showed how past declination and inclination data could be utilized for this purpose. The solution there proposed will be effectively advanced by the use of the energy function. I shall enter into this matter more fully in a paper entitled "On the Time Extension of the Gaussian Analysis."

A few examples will serve to illustrate the practical application of the energy function.

1. *What work is required at Washington to move a unit magnetic pole, repelled by the Earth's field, from a height where the Earth's magnetic force has vanished down to the Earth's surface?*

According to formula three

$$w = d\,W = -\frac{1}{8\pi} V Z\, d\,S \quad .$$

For the case considered, we have, approximately for 1885, in *C. G. S.* units, $V = -0.26\ R$, $Z = 0.57$, $d\,S =$ element of surface, taken as one square cintemeter. [For many purposes it will be sufficient to take $V/R = -\frac{1}{2}\ Z$, as will be the case for a homogeneous magnetization.] Taking R in cms. $= 6.37 \times 10^8$,

$$w = \frac{1}{8\pi}[(0.26) \times (0.57) \times 6.37 \times 10^8] = 3.76 \times 10^6 \text{ ergs} = 0.0383$$

kilogrammeters $= 0.277$ foot pounds $= 3\frac{1}{3}$ inch pounds; that is, the work performed would be equal to raising a pound or about a half kilogram, $3\frac{1}{3}$ inches high against the Earth's gravitational force.

For the vicinity of the north magnetic pole, where we may take $Z = 0.61$, $V/R = -0.32$ or about $\frac{1}{2}\ Z$, $dS = 1$ sq. cm., $w = 4.95 \times 10^6$ ergs $= 0.0504$ kilogrammeters $= 0.365$ foot pounds $= 4.4$ inch pounds. *For points vertically above the magnetic equator*, since here $Z = 0$, $w = 0$. *For the entire Earth*, the mean of the seven values in the last column of Table V gives $W = 0.03576 \times R^3 = 9.243 \times 10^{24}$ ergs $= 9.422 \times 10^{16}$ kgms. $= 68.15 \times 10^{16}$ foot

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pounds. Per square centimeter of surface we have, $w = 1.812 \times 10^6$ ergs $= 0.0185$ kgm. $= 0.134$ foot pounds $= 1.6$ inch pounds.

By turning back to table V, we find that the average values of the magnetic energy arising from the various constituent portions of the Earth's permanent magnetism are:

	I	II	III	IV	Total
$W/R^3 =$	0.03525	0.000317	0.000153	0.000037	0.03576

Hence W_{II} is about $\frac{1}{100} W_I$, W_{III} is about $\frac{1}{200} W_I$, and W_{IV}, about $\frac{1}{1000} W_I$. The magnetic energy of that portion of the Earth's permanent magnetic field represented by the residual field in No. I of these researches, namely, the terms II, III, and IV, is 0.000507 $R^3/0.03525$ R^3 or about $\frac{1}{70}$ that arising from the homogenous magnetization taken as the normal field. If simply the homogenous magnetization symmetrical about the Earth's rotation axis be taken as the normal field, then the magnetic energy of the residual portion will be $0.001915\ R^3/0.03385\ R^3$, or $\frac{1}{17.7}$ that of the symmetrical field. This latter ratio is about 100 times that existing between the magnetic energies of the external portion of the diurnal variation field and the external portion of the permanent field.

2. *What is the total work required to remove a gram mass from every point of the Earth's surface to a height where the Earth's gravitational force has vanished?*

If M be the Earth's total mass, r the radius vector to any point in the space outside, then the gravitation potential will be $V = M/r$ and the vertical force, $Z = M/R^2$

$$\text{hence, } dW = \frac{1}{8\pi} VZ\, dS = \frac{1}{8\pi} \frac{M^2}{R^3} dS .$$

Integrating over the entire Earth's surface, in accordance with formula three, we get for the Earth's gravitational energy in the space outside:

$$W = \frac{M^2}{2R} = \frac{(6.14 \times 10^{27})^2}{2 \times 6.37 \times 10^8} = 2.96 \times 10^{46} \text{ ergs} =$$

0.302×10^{39} kgms. $= 2.18 \times 10^{39}$ foot pounds. Per square centimeter, we have, $w = 0.582 \times 10^{28}$ ergs $= 0.0593 \times 10^{21}$ kgms. $= 0.429 \times 10^{21}$ foot pounds. For a square element of surface with sides 0.4 millimeter long, $w = 9.31 \times 10^{24}$ ergs $= 9.49 \times 10^{16}$

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kgms. $= 68.64 \times 10^{16}$ foot pounds. *Hence the gravitational energy over a square 0.4 mm. of surface is equal to the Earth's total magnetic energy over the entire surface.*

3. An application of the energy function to the *diurnal variation forces* has likewise been made, and it would appear, that if we take into consideration the external portion of the Earth's permanent magnetic field, in addition to the diurnal variation field, we are dealing with a distribution of forces in the upper regions, very similar to that of the permanent field, and that the difference is merely one of degree, and, as to the seat of the forces,—whether internal or external. These calculations will furnish the subject of a separate paper.

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b. THE SEAT OF THE PRINCIPAL CAUSE OF THE SECULAR VARIATION OF THE EARTH'S MAGNETISM.

Innumerable hypotheses have been advanced for the cause of the secular variation, but to my knowledge, the only attempt made to settle the question, which must first be answered, before a successful determination of the cause can be made, as to the *seat* of the cause of the secular variation—whether within the Earth's crust or outside of it,—was my preliminary one, in this Journal, Vol. IV, 1899, pp. 54–58.

I there solved the problem for that portion of the Earth's magnetism, which can be referred to a homogeneous magnetization, with the aid of the following proposition:

"If the observed changes in the compass and the dip needle, can be completely accounted for by hypothetical causes within the Earth's crust, then they can not be produced by causes outside of the crust."

The secular changes in the *compass* needle can equally well be explained by internal or external causes. By taking, however, into account also the secular changes in *dip*, it can be determined whether the principal cause of the secular variation is an internal or an external one.

The general conclusion drawn was, that the seat of the principal cause, was within the Earth's crust.

I shall now reinvestigate this matter, considering this time the changes in the three magnetic elements, declination, dip, and intensity, during the period from 1840–1845 (Sabine's charts), to 1880–1885 (Creak and Neumayer's charts), and use the same analytical method employed by Gauss, in determining whether the Earth's permanent magnetic field arose from an internal or an external system, and later by Schuster, when solving the same question, with respect to the diurnal variation.

The potential due to an internal system of magnetic forces may be expressed as follows:

$$V_i = \frac{R^3}{r^2} \cdot P_1 + \frac{R^4}{r^3} \cdot P_2 + \frac{R^5}{r^4} \cdot P_3 + \ldots, \qquad (1)$$

and the potential due to an external system of magnetic forces:

$$V_e = r \cdot P_1 + \frac{r^2}{R} \cdot P_2 + \frac{r^3}{R^2} \cdot P_3 + \ldots. \qquad (2)$$

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r, is the radius vector from the center of the Earth to the point considered; R, the Earth's mean radius, and P_1, P_2, P_3, etc., surface spherical harmonics.

On the surface of the Earth, $r = R$, we have

$$V_i = V_e, \; X_i = X_e \text{ and } Y_i = Y_e \quad , \tag{3}$$

$$Z_i = -2P_1 - 3P_2 - 4P_3 - \ldots \quad , \tag{4}$$

$$Z_e = +P_1 + 2P_2 + 3P_3 + \ldots \quad . \tag{5}$$

Hence, with the aid of the vertical force, it can be ascertained whether the system producing a given magnetic distribution, is an internal or an external one, or both. For a system of coefficients which will satisfy the X and Y values on the Earth's surface, can not fulfill at the same time, both conditions expressed by the Z_i and Z_e equations. *If the Z_i condition is fulfilled, then the system is an internal one, and if, on the other hand, the Z_e condition is satisfied, then the system is an external one, at least as far as the principal effects are concerned.* Again, by the degree of divergence in the fulfillment of either condition, it can be determined as to how much of the observed effects are to be ascribed to a system external to the principal one.

This is the method used by Gauss and Schuster, when solving their respective problems, as already stated.

Precisely similar equations, to the above hold for any magnetic variation possessing a potential. Let dV, dX, dY, and dZ, represent, respectively, the average annual change in V, X, Y, and Z, during the interval 1840–1845 to 1880–1885, *i. e.*, during a period about forty-two years. Furthermore, X_1, Y_1, Z_1, and X_2, Y_2, Z_2, shall represent, respectively, the mean magnetic components along a complete parallel of latitude, for the early and the later epoch.

$$\Delta X = X_1 - X_2 \quad , \Delta Y = Y_1 - Y_2 \quad , \Delta Z = Z_1 - Z_2$$

$$dX = \tfrac{1}{42}\,\Delta X \quad , dY = \tfrac{1}{42}\,\Delta Y \quad , dZ = \tfrac{1}{42}\,\Delta Z \; .$$

We have to terms of the fourth order:

$$X = -g_{10}\sin u - 2\,g_{20}\sin u\cos u - 3\,g_{30}(\cos^2 u - \tfrac{1}{5})\sin u - 4\,g_{40}(\cos^2 u - \tfrac{3}{7})\sin u\cos u \quad , \tag{6}$$

$$Y = 0 \quad , \tag{7}$$

$$Z_i = -2\,g_{10}\cos u - 3\,g_{20}(\cos^2 u - \tfrac{1}{3}) - 4\,g_{30}(\cos^2 u - \tfrac{3}{5})\cos u - 5\,g_{40}(\cos^4 u - \tfrac{6}{7}\cos^2 u + \tfrac{3}{35}) \quad , \tag{8}$$

$$Z_e = +g_{10}\cos u + 2\,g_{20}(\cos^2 u - \tfrac{1}{3}) + 3\,g_{30}(\cos^2 u - \tfrac{3}{5})\cos u + 4\,g_{40}(\cos^4 u - \tfrac{6}{7}\cos^2 u + \tfrac{3}{35}) \quad . \tag{9}$$

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These equations being linear in the coefficients g, precisely similar equations pertain to the differentials; we have simply to substitute dX for X, dg for g, etc.

If, as is usually done in the initial steps of a potential computation, the X, Y, Z, components for points along the same parallel of latitude, are expressed in the form of a series:

$$X = m_0 + m_1 \cos \lambda + M_1 \sin \lambda + m_2 \cos {}_2\lambda + M_2 \sin {}_2\lambda + \ldots \quad (10)$$

$$Y = l_0 + l_1 \cos \lambda + L_1 \sin \lambda + l_2 \cos {}_2\lambda + L_2 \sin {}_2\lambda + \ldots \quad (11)$$

$$Z = k_0 + k_1 \cos \lambda + K_1 \sin \lambda + k_2 \cos {}_2\lambda + K_2 \sin {}_2\lambda + \ldots \quad (12)$$

then will $X = m_0$, $Y = l_0$ and $Z = k_0$. (13)

$$\Delta X = \Delta m_0 \text{ , } \Delta Y = \Delta l_0 \text{ and } \Delta Z = \Delta k_0 \quad . \quad (14)$$

The values of m_0, l_0, k_0, have been determined by Adams and Fritsche, from the magnetic elements on Sabine's charts for 1840–1845, by Adams for 1880, from Creak's chart of 1880, and by Fritsche, Neumayer and Schmidt, from Neumayer's chart for 1885. As Fritsche's values for 1842 are dependent upon scalings for points 30° apart in longitude, and his later values for 1885 for points 15° apart in longitude, whereas Adams' values for both epochs depend upon scalings 10° apart, I have confined myself for the m_0 values entirely to the latter's values, as representing fuller and more homogeneous data.

Theoretically, according to the above formulæ, $Y = l_0 = 0$. As a matter of fact, however, l_0 is not quite equal to zero,[1] thus indicating the possible existence of effects arising from a system not possessing a potential, *e. g.*, electric currents passing vertically through the Earth's crust, either from within or without, or from both sources. However, the departures from zero are of such an amount, that for the present investigation, we can leave them out of consideration. We can thus confine ourselves entirely to determining Δg_{10}, Δg_{20}, Δg_{30}, Δg_{40}, from the $\Delta X = \Delta k_0$ values. If the values thus found, satisfy the ΔZ_i equation, then it has been proven that the seat of the principal source of the secular variation is within the Earth, and if, on the other hand, the ΔZ_e condition is better fulfilled, then the seat is outside of the Earth.

If Δk_0 and $\Delta k_0'$, represent the average ΔX values on two parallels, u and $180-u$ (*i. e.*, on two parallels equi-distant from the equator), we have the conditional equations:

[1] *T. M.* Vol. II, p. 17.

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$$\tfrac{1}{2}(\Delta k_0 + \Delta k'_0) = -\Delta g_{10} \sin u - 3\,\Delta g_{30}(\cos^2 u - \tfrac{1}{5}) \sin u \quad , \quad (15)$$

$$\tfrac{1}{2}(\Delta k_0 - \Delta k'_0) = -2\,\Delta g_{20} \sin u \cos u - 4\,\Delta g_{40}(\cos^2 u - \tfrac{3}{7}) \sin u \cos u \quad , \quad (16)$$

for each pair of parallels employed, viz: 60° N. and S., 50° N. and S., 40° N. and S., 30° N. and S., 20 N. and S., and 10° N. and S., the equator not being used, so as to preserve the uniformity of the system of equations.

	½ (k + k′) Brit. Units.		½ (k + k′) C. G. S. Units.		½ (Δk + Δk′) C. G. S. Units.		½ (Δk − Δk′) C. G. S. Units.	
Parallels	1842.5	1880	1842.5	1880	Observ'd	Comp'd	Observed	Comp'd
60 N. and S.	3.1453	3.0990	0.1450	0.1429	+ 0.0021	+ 0.0039	— 0.0020	— 0.0012
50 " " "	4.1814	4.0501	0.1928	0.1867	+ 61	+ 48	— 42	— 46
40 " " "	5.1196	4.9913	0.2361	0.2301	+ 60	+ 55	— 78	— 81
30 " " "	5.9998	5.8674	0.2766	0.2705	+ 61	+ 60	— 96	— 101
20 " " "	6.7362	6.6060	0.3106	0.3046	+ 60	+ 63	— 82	— 92
10 " " "	7.2384	7.1009	0.3337	0.3274	+ 63	+ 64	— 70	— 55

The values ½ ($k_0 + k'$) and ½ ($k_0 - k'$), as used in above table, have been taken from Vol. II, pp. 520–523, of "The Scientific Papers of John Couch Adams;" they are given there in British units, and have been converted by me into C. G. S. units. Columns 6 and 8, give the quantities used in the determination of the values Δg by least squares. The first number in column 6, for instance, represents the average secular change in the X component along the parallels 60° N. and S., for the entire interval 1842.5 to 1880, the plus sign signifying that X, on the average, decreased during that period. To obtain the average annual change, dX, the numbers would have to be divided by the elapsed interval of 37.5 years.

The resulting values of Δg, expressed in C. G. S. units, are: $\Delta g_{10} = -0.00685$, $\Delta g_{20} = +0.00795$, $\Delta g_{30} = -0.00047$, and $\Delta g_{40} = -0.01025$. Hence the annual increments from division by 37.5: $dg_{10} = -0.000183$, $dg_{20} = +0.000212$, $dg_{30} = -0.000013$, $dg_{40} = -0.000273$.

How closely the computed Δg's[1] will reproduce the observed values, can be seen from columns 7 and 9.

[1] We have a check upon our values from Adams' own computations. He computed the g's for both epochs, once from the X and Y components alone, and next from the Z components, and thus got two sets of values for each epoch (see p. 607 of volume above cited); his values are slightly different from mine as he included terms to the 6th order. Converting into C. G. S. units we obtain from his X, Y, figures: $\Delta g_{10} = -0.0066$, $\Delta g_{20} = +0.0077$, $\Delta g_{30} = -.0006$, $\Delta g_{40} = -0.0094$, $\Delta g_{50} = +0.0033$, and $\Delta g_{60} = +0.0042$.

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If now the principal cause of the secular variation is an internal one, then the above Δg values must satisfy this condition:

$$\Delta Z_i = -2\,\Delta g_{10}\cos u - 3\,\Delta g_{20}(\cos^2 u - \tfrac{1}{3}) - 4\Delta\, g_{30}(\cos^2 u - \tfrac{3}{5})\cos u - 5\Delta\, g_{40}(\cos^4 u - \tfrac{6}{7}\cos^2 u + \tfrac{3}{35}) \quad . \qquad (17)$$

If, on the other hand, the principal cause is an external one, then the other condition must be fulfilled:

$$\Delta Z_e = +\Delta g_{10}\cos u + 2\,\Delta g_{20}(\cos^2 u - \tfrac{1}{3}) + 3\,\Delta g_{30}(\cos^2 u - \tfrac{3}{5})\cos u + 4\,\Delta g_{40}(\cos^4 u - \tfrac{6}{7}\cos^2 u + \tfrac{3}{35}) \quad . \qquad (18)$$

The figures in the following table show the result of the test of both hypotheses; the value of each term in each expression is given, so as to show its effect and magnitude. It is most instructive to exhibit the law of variation in ΔZ from parallel to parallel, instead of a pair of equi-distant parallels, and as Adams only gives the Z^m (or m_o) values for pairs of parallels, I have made use of de Tillo's tabulations of Z, for points 10° apart in longitude. All the quantities in the table are in terms of the fourth decimal, C. G. S., units, hence, in terms of 10γ.

Lat.	Observation.			I. Computation: cause internal						II. Computation: cause external					
	$Z^m = m_o$		ΔZ_o^m	Term				I ΔZ_c^m	Obs'd-Co'pd	Term				E ΔZ_c^m	Obs'd-Co'pd
	1842.5	1885	'42–'85	1	2	3	4			1	2	3	4		
N60°	+5488	+5430	+ 58	+119	−99	+2	+0	+ 22	+ 36	−59	− 66	−2	−0	+ 5	+ 53
50°	+5032	+5000	+ 32	+105	−60	0	−4	+ 41	− 9	−52	+ 40	0	+3	− 9	+ 41
40°	+4420	+4303	+117	+ 88	−19	−2	−5	+ 62	+ 55	−44	+ 13	+2	−4	− 25	+142
30°	+3449	+3464	− 15	+ 68	+20	−3	−3	+ 82	− 97	−34	−13	+ 2	+ 3	− 42	+ 27
20°	+2340	+2295	+ 55	+ 47	+51	−3	0	+ 95	− 40	−23	−34	+2	0	− 55	+110
10°	+1124	+1022	+102	+ 24	+72	−2	+3	+ 91	− 11	−12	−48	+2	−3	− 61	+163
Equ'r	− 96	− 221	+125	0	+79	0	+4	+ 83	+ 42	0	−53	0	−4	− 57	+182
10°	−1262	−1359	+ 97	− 24	+72	+2	+3	+ 53	+ 44	+12	−48	−2	−3	− 41	+138
20°	−2286	−2398	+112	− 47	+51	+3	0	+ 7	+105	+23	−34	−2	−0	− 13	+125
30°	−3200	−3226	+ 26	− 68	+20	+3	−3	− 48	+ 74	+34	−13	−2	+3	+ 22	− 4
40°	−4087	−3927	−160	− 88	−19	+2	−5	−110	− 50	+44	+13	−2	−4	+ 59	−219
50°	−4823	−4600	−223	−105	−60	0	−4	−169	− 54	+52	+40	0	+3	+ 95	−318
S60°	−5437	−5209	−228	−119	−99	−2	0	−220	− 8	+59	−66	−2	0	+127	−355

The fourth column contains the secular change in the vertical component during the interval 1842.5 to 1885, on the average, for the respective parallel opposite to which it stands, a plus sign signifying that the vertical force has decreased during the said period. The columns marked I and E, respectively, give the computed secular changes for the two hypotheses: internal and external; the residuals contained in the columns adjacent (on the right) to I and E,

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enable one to judge as to which of the two hypotheses appears the more probable one. It is readily seen that the hypothesis of an internal cause gives the smaller residuals. The diagram (Fig. 1) tells the story best.

The curves shown, express the law of variation in the average secular change of the vertical component, from parallel to parallel, the full curve as dependent on observations between 1842 and 1885, the broken curve being the computed variation upon the hypothesis of an internal cause, whereas the dotted curve being the computed variation as on the hypothesis of an external one. It will be noticed, that while the observed curve is irregular, it agrees in general well with the internal-cause curve, and disagrees markedly from the external-cause curve.

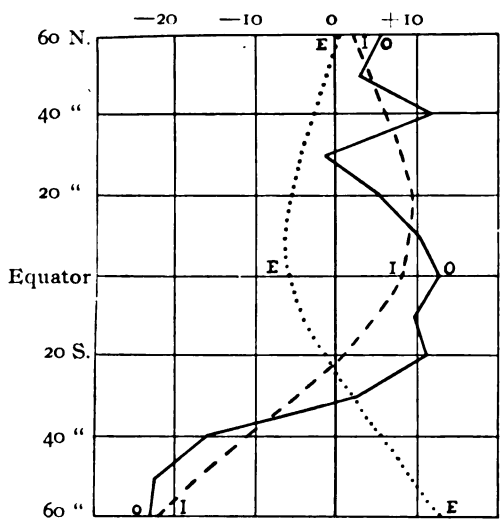

FIG. 1. Comparison of observed (full curve) with computed secular variation (broken curve supposing cause internal, and dotted curve supposing cause external.)

In order to find out whether the irregularities in the observed curve are due to errors in de Tillo's tabulated quantities, I have also plotted the curve as dependent on Fritsche's m_0 values for 1842.5 and 1885; his first values, as already stated, depend upon 30° scalings, and the latter upon scalings made 15° apart in longitude. The curve thus obtained, agreed so well with the one already given, that, to avoid confusion, it was omitted in the reproduction. The irregularities are, therefore, inherent in the primary quantities, and

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from other investigations, I am conducting, I am inclined to think that they are, to a large extent, facts of nature. These irregularities are most pronounced near parallels 20–30, N. and S.—parallels of such interest to the meterologist.

It is quite possible, of course—in fact probable—that in addition to the main internal cause of the secular variation, there is, in addition, a subordinate, external cause. The investigation of this is reserved for a future paper.

The conclusion drawn from this paper, is that:

The main cause of the secular variation of the Earth's magnetism is due to a system of forces imbedded in the Earth, and not to an external system. This does not exclude there being, in addition, an external system producing minor effects. The main cause is due, furthermore, to a system of forces possessing a potential.

c. ON THE IMPROVEMENT OF THE GAUSSIAN THEORY OF THE EARTH'S MAGNETISM.

As it is my intention to make some time a new mathematical analysis of the Earth's magnetic field, on somewhat different principles than hitherto employed, I am making a critical examination and comparison of the results obtained thus far by the various analysts, with the view of ascertaining precisely wherein improvement is required. The conclusions reached, thus far, follow from the tables herein presented.

Table *A*, gives the residuals obtained by subtracting the computed X components from the so-called observed values or values based upon the magnetic charts used in the potential computation. Thus, beginning with the second column, marked F, we have the residuals for every 30° in longitude along the parallel 60° N, the computed quantities, X_c, resulting from Fritsche's analysis for 1840–1845, as dependent upon the Sabine's charts for that period. Fritsche scaled from these maps, the declination, inclination, and horizontal intensity for every 10th degree parallel, 80 N. to 80 S., and for every 30th degree meridian, and from these scaled quantities, computed the X_o, Y_o, Z_o's. Having deduced the Gaussian coefficients to terms of the sixth order, as given in the table in section *a* of this paper, he next computed the X_c, Y_c, Z_c's, and formed the residuals, which are here reproduced with the signs changed to conform with the notation adopted in this paper. [X + north, Y or D, + east, Z or I, + down, $\Delta X = X_o - X_c$ etc.]

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TABLE A. Residuals of X components for 1842.5 and 1885, according to Fritsche and Schmidt. ($X_o - X_c$).

[Expressed in units of fourth decimal, *C. G. S.*]

	1842	60° N. 1885			1842	40° N. 1885			1842	20° N. 1885			1842	Equator. 1885			1842	20° S. 1885			1842	40° S. 1885			1842	60° S. 1885			
λ E of Gr	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	λ E of Gr
0	+ 13	+ 71	− 5	+ 76	− 61	− 3	+45	− 48	+ 10	60	−35	− 25	+ 92	+ 29	+14	+ 15	− 98	−90	−49	−41	−70	−17	+21	− 38	− 61	−121	−43	− 78	0
15		+ 99	− 6	+105		− 31	+ 5	− 36		− 65	−24	− 41		+ 31	+11	+ 20		−49	−20	−29		+10	− 39	− 29		−122	−40	− 82	15
30	+ 7	+131	+ 12	+119	− 78	− 16	−16	0	+232	− 50	−16	− 34	−144	− 9	+13	− 22	− 99	− 6	+16	−16	−35	+18	+29	+ 19	− 75	− 81	−16	− 65	30
45		+141	+ 35	+106		+ 14	−26	+ 40		− 11	− 3	− 8		− 46	+23	− 68		0	+17	−17		+77	− 1	+ 78		− 65	−21	− 44	45
60	+ 70	+138	+ 51	+ 87	+ 38	+ 25	−40	+ 65	− 30	+ 35	+13	+ 22	+ 81	− 70	+ 8	− 78	+ 51	+11	+19	− 8	+52	+91	−14	+105	− 31	− 70	−35	− 35	60
75		+120	+ 41	+ 79		+ 37	−38	+ 75		+ 95	+ 50	+ 45		− 73	−26	− 47		+ 1	− 9	+ 10		+73	−10	+ 83		−104	−61	− 43	75
90	+ 24	+135	+ 52	+ 83	+ 81	+ 45	−39	+ 84	+122	+ 60	+16	+ 53	+191	− 13	− 4	− 9	+ 65	− 9	−23	+14	+11	+55	+16	+ 39	− 38	− 93	−48	− 45	90
105		+156	+ 70	+ 86		+ 71	− 8	+ 79		+ 17	−32	+ 49		+ 11	+11	0		−11	−12	+ 1		+94	+43	+ 21		+ 3	+ 18	− 15	105
120	+ 52	+134	+ 54	+ 80	+ 11	+ 58	+ 7	+ 51	+ 85	+ 19	−22	+ 41	+118	+ 30	+31	− 1	+ 33	+ 8	+11	− 3	−37	+82	+35	+ 47	− 24	+ 21	−26	+ 47	120
135		+ 76	+ 6	+ 70		+ 44	+31	+ 13		+ 35	−12	+ 47		+ 98	+ 70	+ 28		+ 50	+ 35	+ 15		+105	+10	+ 85		+ 31	−72	+103	135
150	+ 27	+ 32	− 49	+ 81	− 81	+ 59	+52	+ 7	+ 73	+ 66	− 6	+ 72	+ 93	+ 58	−20	+ 78	+ 8	+81	+36	+45	−78	+46	−45	+ 91	+ 43	+ 32	−89	+121	150
165		+ 32	− 81	+113		+ 60	+ 9	+ 51		+105	+ 4	+101		− 50	−61	+111		+ 91	+ 31	+ 63		+19	−35	+ 54		+ 12	−74	+ 86	165
180	+ 5	+ 43	−107	+150	+ 40	+ 34	−71	+105	− 4	+113	+12	+101	+ 80	+112	+11	+101	+210	+96	+33	+63	−32	+12	+11	+ 1	+ 8	+ 13	−18	+ 31	180
195		+ 61	− 99	+160		+ 55	−54	+109		+ 94	+26	+ 68		+ 87	+15	+ 72		+ 83	+ 28	+ 55		+ 12	+15	− 33		+ 30	+40	− 10	195
210	− 66	+ 87	− 48	+135	+ 19	+ 84	+28	+ 56	− 40	+ 28	+ 7	+ 21	+143	+ 35	−20	+ 55	+ 63	+56	+11	+45	+ 5	−27	+12	− 39	+ 39	+ 51	+ 62	− 11	210
225		+ 88	− 14	+102		+ 68	+64	+ 4		− 6	−10	+ 4		− 11	−64	+ 53		+19	− 3	+22		−60	−31	− 29		+ 70	+63	+ 7	225
240	− 1	+ 88	− 1	+ 89	− 24	+ 40	+30	+ 10	− 14	− 11	−28	+ 17	+147	+ 52	+ 7	+ 45	+ 92	+22	+26	− 4	− 2	−57	−44	− 13	+111	+ 87	+66	+ 21	240
255		+ 82	− 15	+ 97		+ 78	+17	+ 61		− 11	−53	+ 42		+ 45	+13	+ 32		+45	+50	−11		−26	−18	− 8		+ 75	+68	+ 7	255
270	+ 6	+ 7	− 97	+104	− 38	+ 83	−18	+101	+ 69	+ 18	−32	+ 50	+ 17	+ 23	− 7	+ 30	− 60	+32	+17	−15	+65	+ 5	+ 7	− 2	+ 34	+ 5	+32	− 27	270
285		+ 33	− 54	+ 87		+105	+16	+ 89		+ 57	+17	+ 40		− 2	−42	+ 40		+ 5	−41	+ 36		+31	+29	+ 2		+ 3	+64	− 61	285
300	− 22	+ 45	− 8	+ 51	−112	+ 28	−17	+ 45	+ 40	+ 63	+34	+ 34	+ 67	− 37	−77	+ 40	− 57	+22	−20	+42	+42	0	− 9	+ 9	− 11	− 9	+66	− 75	300
315		+ 11	− 8	+ 19		− 41	−43	+ 2		+ 37	+ 3	+ 34		+ 61	+46	+ 15		+23	+27	− 4		−17	−26	+ 9		− 60	+10	− 70	315
330	+ 32	+ 3	− 9	+ 12	+ 52	− 45	−27	− 21	− 60	− 26	−53	+ 27	+ 97	+ 30	+43	− 13	+ 41	−24	+28	−52	− 4	−33	−36	+ 3	+ 47	− 89	−28	− 61	330
345		+ 38	+ 2	+ 36		− 5	+34	− 39		− 30	−40	+ 4		− 7	+ 1	− 8		−75	−10	−65		−32	12	− 20		−114	−48	− 66	345
Mean	27.1	77.1	38.5	88.6	52.9	47.2	30.6	49.6	64.9	47.2	22.8	40.8	10.6	42.5	26.6	40.9	73.1	38.0	23.8	29.5	36.1	41.2	24.1	35.7	43.8	57.1	46.2	50.5	Mean

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TABLE B. Residuals of Y components for 1842.5 and 1885, according to Fritsche and Schmidt. $(Y_o - Y_c)$.

[Expressed in units of fourth decimal, *C. G. S.*]

	1842	60° N. 1885			1842	40° N. 1885			1842	20° N. 1885			1842	Equator. 1885			1842	20° S. 1885			1842	40° S. 1885			1842	60° S. 1885			
λ *E* of Gr	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	λ *E* of Gr
0	− 40	−22	+44	−66	+22	+47	+ 34	+13	− 23	+111	+23	+ 88	−41	+ 44	− 20	+ 64	−12	−18	− 5	−13	+ 33	+ 27	+ 56	− 29	+ 14	+ 29	+ 49	− 20	0
15		−29	− 6	−23		−18	− 25	+ 7		+ 25	+25	0		+ 28	+ 40	− 12		+11	+24	−13		− 26	− 18	− 8		+ 24	+ 37	− 13	15
30	− 15	−16	−44	+28	−54	−44	− 53	+ 9	−106	− 58	+18	− 76	+12	− 22	+ 54	− 76	+ 7	− 5	− 6	+ 1	− 15	− 69	− 85	+ 16	− 21	+ 28	+ 33	− 5	30
45		+ 25	−34	+ 59		−13	− 42	+29		− 58	+ 7	− 65		− 33	+ 20	− 53		−14	−17	+ 3		− 91	− 79	− 12		+ 37	+ 42	− 5	45
60	+ 54	+62	+ 2	+60	− 3	+37	+ 5	+32	− 56	− 49	−43	− 6	−52	− 18	− 29	+ 11	+29	+17	+38	−21	+ 57	− 69	+ 10	− 79	+ 53	+ 33	+ 43	− 10	60
75		+69	+33	+36		+60	+ 53	+ 7		− 29	−48	+ 19		− 23	− 66	+ 43		−14	+27	−41		− 59	+ 54	−113		+ 15	+ 6	+ 9	75
90	+ 40	+36	+19	+17	−83	+87	+106	−19	− 35	+ 19	+21	− 2	−21	+ 10	− 24	+ 34	−14	+ 1	+21	−20	− 71	− 36	+ 23	− 59	+ 28	+ 16	− 47	+ 63	90
105		+ 2	−15	+17		+29	+ 27	+ 2		+ 69	+72	− 3		+ 67	+ 42	+ 25		+39	+ 4	+35		+ 9	− 30	+ 39		+116	− 6	+122	105
120	− 50	+ 7	−23	+30	−77	−12	− 67	+55	+ 5	+ 36	− 5	+ 41	+24	+ 58	+ 20	+ 38	−35	+62	− 5	+67	+ 23	+ 63	− 26	+ 89	+156	+147	+ 9	+138	120
135		−20	−48	+28		−52	−123	+71		+ 13	−54	+ 67		+ 11	− 34	+ 45		+27	−15	+42		+ 24	− 19	+ 43		+ 72	− 18	+ 90	135
150	+ 30	−12	−22	+10	−51	+ 8	− 8	+16	− 2	+ 18	− 8	+ 26	− 6	+ 31	+ 2	+ 29	+43	+14	+21	− 7	+ 2	− 36	+ 19	− 55	+ 8	+ 9	+ 3	+ 6	150
165		+30	+33	− 3		+43	+ 90	−47		+ 24	+54	− 30		+ 39	+ 21	+ 18		−11	+15	−26		− 76	+ 39	−115		− 2	+ 66	− 62	165
180	+109	+41	+26	+15	0	+46	+ 87	−41	− 16	+ 3	+30	− 27	−44	+ 30	+ 5	+ 25	− 8	−40	−29	−11	− 23	− 73	+ 26	− 99	− 52	− 29	+ 52	− 81	180
195		+31	−25	+56		− 9	− 40	+31		− 31	−54	+ 23		− 4	− 20	+ 16		−30	−25	− 5		− 58	− 20	− 38		− 65	− 6	− 59	195
210	− 10	− 6	−86	+ 80	+41	− 9	− 85	+76	+ 25	− 14	−42	+ 28	+99	− 66	− 26	− 40	−11	−12	+ 22	−34	− 22	− 24	− 34	+ 10	− 76	− 77	− 45	− 32	210
225		−11	−79	+68		− 3	− 31	+28		− 16	+26	− 42		−100	+ 11	−111		−11	+60	−71		− 22	− 37	+ 15		− 93	− 60	− 33	225
240	− 17	+ 5	−24	+29	− 9	− 8	+ 51	−59	− 53	− 47	+59	−106	−45	−125	− 11	−114	+39	−20	+48	−68	− 18	− 63	− 47	− 16	− 63	− 87	− 22	− 65	240
255		+ 1	− 3	+ 4		+17	+103	−86		− 62	+17	− 79		− 74	− 39	− 35		−22	+12	−34		− 81	− 26	− 55		− 40	+ 62	−108	255
270	− 26	−30	−36	+ 6	+13	− 1	+ 28	−29	+ 16	− 43	−53	+ 10	−14	+ 11	− 23	+ 34	+38	− 4	+ 6	−10	+ 81	− 26	+ 39	− 65	+ 37	+ 49	+173	−124	270
285		+23	0	+23		+ 8	− 36	+ 44		− 8	−59	+ 51		− 43	− 50	+ 7		−55	−32	−23		− 25	+ 8	− 33		+ 77	+177	−100	285
300	− 3	−17	−33	+16	−14	+ 5	− 57	+62	− 20	+ 45	+35	+ 10	−38	− 12	+ 70	− 82	−54	−68	−19	−49	+ 20	− 40	− 67	+ 27	+ 60	+ 29	+ 77	− 48	300
315		−12	+ 7	−19		+36	+ 5	+31		+ 32	+69	− 28		+ 8	+124	−116		−32	+15	−47		− 6	− 69	+ 63		+ 14	+ 23	− 9	315
330	− 19	−18	+44	−62	+54	+40	+ 33	+ 7	+ 38	− 52	−66	+ 14	+20	− 98	− 58	− 40	+36	−14	+13	27	+ 14	+ 42	− 5	+ 47	+ 16	+ 9	+ 8	+ 1	330
345		−26	+56	−82		+56	+ 51	+ 5		+ 71	−16	+ 87		− 65	−121	+ 56		− 1	+11	−12		+ 60	+ 62	− 2		+ 25	+ 36	− 11	345
Mean	34.4	23.0	30.9	34.9	35.1	28.7	51.7	33.5	32.9	38.9	37.3	38.7	35.4	42.5	38.7	46.8	27.1	22.6	20.4	28.3	31.6	46.1	37.4	46.9	48.7	47.0	45.6	50.6	Mean

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TABLE C. *Residuals of Z Components for 1842.5 and 1885, according to Fritsche and Schmidt.* ($Z_o - Z_c$).

[Expressed in units of fourth decimal, *C. G. S.*]

	1842	60° N. 1885			1842	40° N. 1885			1842	20° N. 1885			1842	Equator. 1885			1842	20° S. 1885			1842	40° S. 1885			1842	60° S. 1885			
λ *E* of *Gr*	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	F	N F	N S	S F	λ *E* of *Gr*
°																													°
0	+ 8	+ 32	− 61	+ 93	− 38	+ 35	+ 38	− 3	+151	− 89	− 26	− 63	− 13	− 68	− 67	− 1	+ 73	+117	− 4	+121	+150	+ 70	− 39	+109	+133	+ 78	+ 22	+ 56	0
15		+ 2	− 79	+ 81		− 33	− 38	+ 5		−134	− 80	− 54		−131	− 89	− 42		+121	+83	+ 38		+107	+ 48	+ 59		+ 33	− 8	+ 46	15
30	− 74	+ 52	+ 21	+ 31	+ 60	−104	− 60	− 44	− 15	− 58	+ 22	− 80	+ 3	− 83	+ 7	− 90	+ 3	+ 9	+54	− 45	+ 18	+ 90	+ 89	+ 1	+ 19	+ 20	− 12	+ 32	30
45		+117	+151	− 34		− 97	+ 8	−105		− 38	+ 51	− 89		− 30	+ 79	− 79		−111	−54	− 57		+ 2	+ 20	− 18		+ 4	− 16	+ 20	45
60	− 10	+117	+202	− 85	+127	−102	+ 13	−115	+ 4	− 53	− 19	− 34	+ 34	+ 48	+ 65	− 17	+137	− 74	−67	− 7	+ 14	− 39	− 43	+ 4	+ 74	+ 29	+ 14	+ 15	60
75		+ 9	+113	−104		− 94	− 24	− 70		− 34	− 69	+ 35		+ 35	+ 19	+ 16		− 37	−64	+ 27		− 3	− 39	+ 31		+ 83	+ 74	+ 9	75
90	+ 77	− 91	+ 7	− 98	+ 46	−128	−103	− 25	+ 16	− 49	− 86	+ 37	− 8	− 57	− 28	− 29	+ 71	− 33	−56	+ 23	− 36	+107	+ 73	+ 34	+130	− 24	− 19	− 5	90
105		− 99	− 20	− 79		− 81	− 74	− 7		− 19	− 5	− 14		− 69	+ 18	− 87		− 45	−50	+ 5		+109	+161	+ 8		− 26	0	− 26	105
120	+135	− 91	− 31	− 60	+ 20	+ 10	+ 18	− 8	+ 33	+ 41	+ 61	− 20	+ 26	+ 6	+ 67	− 61	+161	− 40	−52	+ 12	− 13	+151	+182	− 31	+ 14	− 38	+ 6	− 44	120
135		− 72	− 22	− 50		+ 14	+ 26	− 12		+ 81	+ 48	+ 33		+ 21	− 16	+ 37		− 52	−80	+ 28		+ 38	+105	− 67		+126	+165	− 39	135
150	+ 31	−204	−162	− 42	+ 74	− 37	+ 4	− 41	+ 55	+ 19	− 36	+ 55	− 20	− 14	−101	+ 87	+ 26	− 11	−34	+ 23	+ 82	+ 96	+103	− 67	− 6	+362	+365	− 3	150
165		−216	−185	− 31		− 90	+ 16	−106		−114	− 74	− 40		− 14	− 32	+ 18		+ 36	+ 38	− 2		+ 23	+ 45	− 22		+133	+ 77	+ 56	165
180	+ 40	−140	−134	− 6	− 7	−133	+ 30	−163	−116	−172	+ 1	−173	+197	− 21	+ 72	− 93	+175	0	+15	− 15	+ 85	− 32	− 69	+ 37	+102	+ 33	− 75	+108	180
195		+ 23	− 16	+ 39		−154	− 11	−143		−140	+ 54	−194		− 42	+ 72	−114		− 10	0	− 10		− 78	−136	+ 58		− 55	−184	+126	195
210	− 75	+133	+ 43	+ 90	− 86	−142	− 91	− 51	− 48	− 35	+ 43	− 78	−109	− 51	− 24	− 27	− 22	− 27	−26	− 1	+ 14	− 5	− 22	+ 17	+ 34	−105	−210	+105	210
225		+153	+ 37	+116		−105	−134	+ 26		+ 59	+ 24	+ 35		− 16	− 78	+ 62		− 34	−55	+ 1		+ 61	+108	− 47		−131	−191	+ 60	225
240	+ 84	+254	+145	+109	− 45	− 98	−110	+ 12	− 10	+ 57	+ 39	+ 18	− 2	+ 7	− 56	+ 63	− 15	+ 10	− 5	+ 15	− 16	+ 36	+101	− 65	− 38	−181	−203	+ 22	240
255		+118	+ 47	+ 71		− 35	+ 24	− 59		+ 25	+101	− 76		+ 7	+ 1	+ 6		+ 85	+ 38	+ 47		− 11	+ 19	− 30		−220	−223	+ 3	255
270	− 27	−533	−563	+ 30	+ 20	− 77	+ 22	− 99	+ 14	− 71	+ 21	− 92	+ 40	+ 1	+ 20	− 19	0	+102	+ 44	+ 58	− 55	− 55	− 61	+ 6	−107	−153	−154	+ 1	270
285		+187	+184	+ 3		+ 20	+ 91	− 71		− 71	− 77	+ 6		− 17	− 30	+ 13		+ 21	+ 3	+ 18		− 78	− 77	− 1		+ 13	+ 10	+ 3	285
300	− 41	+116	+119	− 3	+ 17	−102	− 71	− 31	+ 27	+ 9	− 94	+103	+ 59	− 33	− 73	+ 40	+157	− 58	−16	− 42	− 78	− 7	+ 28	− 35	+ 22	+231	+224	+ 7	300
315		+ 63	+ 53	+ 10		−187	−160	− 27		+ 99	+ 15	+ 84		+ 57	+ 30	+ 27		− 50	0	− 50		− 14	+ 18	− 32		+261	+242	+ 19	315
330	− 8	+ 99	+ 54	+ 36	+ 24	−154	−107	− 47	− 36	+ 83	+ 94	− 11	+ 38	+ 54	+ 50	+ 4	− 4	+ 60	+43	+ 26	− 1	− 24	− 53	+ 29	+ 65	+130	+ 93	+ 37	330
345		+134	+ 63	+ 71		− 31	+ 7	− 38		+ 12	+ 82	− 70		− 38	− 41	+ 3		+157	+43	+114		+ 7	− 87	+ 94		+ 61	+ 9	+ 52	345
Mean	50.8	127	105	57.2	47.0	86.1	53.3	54.5	43.8	65.1	50.9	62.2	45.8	37.1	47.3	43.1	70.3	54.5	35.2	32.7	46.8	54.5	82.7	37.6	62.0	106	108	37.2	Mean

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The third column, marked NF, gives the residuals for 1885, resulting from Fritsche's analysis for that date; the residuals are given this time for every 15° in longitude, since in this instance, Fritsche based his computation on quantities scaled from Neumayer's charts for every 15th degree meridian.

The fourth column, marked NS, gives the residuals resulting from Schmidt's analysis for 1885, and the fifth column, marked SF, the residuals between Schmidt's X_c values and Fritsche's (S–F).

At the bottom of the columns we have the mean residuals, supposing all residuals to have the same sign.

Tables B and C, give similarly, the Y and Z residuals.

All of the 1885 residuals in the three tables have been formed by myself, starting with the "observed" components given in Schmidt's publications, and have been checked with the aid of such tables as have been published. Various typographical errors appear to have crept into Schmidt's own tables of residuals, as given in his publications II and III. Fritsche appears to have published the residuals ΔX, ΔY, ΔZ, only for 1842.

I present the residuals simply for parallels 20° apart, from 60 N. to 60 S., as sufficient for the present purpose.

Table D gives the probable errors, r, for each parallel, as based upon the residuals in the foregoing tables, supposing the chart values to be standard ones. If η is the mean residual (regardless of sign), as given at the bottom of the foregoing tables, then, with sufficient approximation for our immediate object, $r = \pm 0.845\ \eta$. At the bottom of this table, the probable errors are given for a mean parallel.

Table E gives the probable errors for the Gaussian analysis (1830), and the Erman-Petersen analysis for 1829; this table is taken directly from the latter's publication (p. 24), the quantities having been converted, however, from conventional Gaussian units into C. G. S., units (1 $C.\ G.\ U = 0.0003494$ C. G. S.). Here the comparison of computed and "observed" quantities is made by the authors ($E.\ P.$) for meridians 40° apart.

By combining the probable errors of X_c, Y_c, and Z_c, the probable errors of the total force F_c are obtained.

The probable errors of H are determined from those of X and Y, whereas those for D (declination) and I (inclination), are formed directly from Fritsche's tables of residuals, of which Tables G give extracts.

We are now prepared to draw our conclusions. Beginning with

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TABLE D. Mean probable errors of the computed components for 1842.5 and 1885.

[Expressed in units of fourth decimal, *C. G. S.*]

Parallel	I 1842.5			1885 X			II 1885 Y			1885 Z			III 1885		
	X F	Y F	Z F	N F	N S	F S	N F	N S	F S	N F	N S	F S	X Mean	Y of F	Z and S
°															
N. 60	±23	±29	±43	±65	±33	±75	±19	±26	±29	± 107	±89	±48	±28	± 2	± 2
40	45	30	40	40	26	42	24	44	28	73	45	46	14	8	46
20	55	28	37	40	19	34	33	32	33	55	43	53	7	0	9
Equ'tr	90	30	39	36	22	35	36	33	40	31	40	36	26	8	10
20	62	23	59	32	20	25	19	17	24	46	30	28	10	0	1
40	30	27	40	35	20	30	39	32	40	46	70	76	8	15	20
S. 60	37	41	52	48	39	43	40	39	43	90	91	31	11	18	12
For Mean Parallel	±53	±30	±45	±44	±26	±43	±31	±33	±34	± 69	±63	±48	±17	±10	±20

TABLE E. Mean probable errors of the computed components for 1829 and 1830.

[Expressed in units of fourth decimal, *C. G. S.*]

Parallel	X		Y		Z	
	1830 G.	1829 E. P.	1830 G.	1829 E. P.	1830 G.	1829 E. P.
°						
N. 67	± 41	± 50	± 60	± 45	± 103	± 106
60	42	63	20	30	124	99
50	69	83	57	49	99	101
40	103	79	66	53	128	113
15	67	75	77	62	140	101
Equator	113	79	65	35	138	119
15	91	67	45	57	110	116
40	187	89	57	36	119	101
60	188	80	157	80	297	108
S. 75	148	74	211	75	368	57
For Mean Par'llel	± 117	± 75	± 99	± 56	± 183	± 102

TABLE F. Average probable errors of the computed elements for zone 60° N. to 60° S.

[The intensity quantities are given in units of fourth decimal, *C. G. S.*]

No.	Analyst.	Epoch	X	Y	Z	F	H	D	I
								°	°
1	Gauss	1830	±117	±99	±183	± 239	±153		
2	Erman-Petersen	1829	75	56	102	138	94		
3	Fritsche	1842.5	53	30	45	76	61	± 0.88	± 0.52
4	"	1885	44	31	69	87	54	0.92	0.66
5	Schmidt . .	1885	26	33	63	75.5	42		
6	Schmidt-Fritsche	1885	43	34	48	73	55		
7	Schmidt and Fritsche .	1885	± 17	±10	± 20	± 28	± 20		

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Table *F*, and leaving out of consideration, for the present, the entries Nos. 6 and 7, it will be noticed that the average probable error in the computed *X* component, for the entire zone of the Earth, 60° N. to 60 S., supposing the observed or chart quantities to be correct, has been steadily reduced until Schmidt's analysis (No. 5) gives a probable error of but $\frac{1}{8}$ of that of Gauss's, $\frac{1}{3}$ that of Erman-Petersen's, and $\frac{1}{2}$ that of Fritsche's for 1842.5. Looking at the probable errors for *Y*, we find for 1842.5, a value about $\frac{1}{3}$ that of Gauss, and $\frac{1}{2}$ that of Erman-Petersen, but since then there has been no reduction. The probable error for *Z*, for 1842.5 is about $\frac{1}{4}$ that of Gauss, and a little less than $\frac{1}{2}$ of Erman-Petersen's. Since 1842.5, there is an increase of about 50 per cent.

Examining next the probable errors for the total force, *F*, Fritsche's probable error for 1842.5, is about $\frac{1}{3}$ of Gauss's and $\frac{1}{2}$ of Erman-Petersen's. His 1885 probable error, however, in spite of the fact that this analysis was based on twice as many points, is about 15 per cent higher than the one for 1842.5. And what is certainly surprising, Schmidt's probable error, although his analysis was the most elaborate, painstaking, and comprehensive one up to date, dependent upon 4½ times the number of points used by Fritsche for 1885, and 9 times the number used by Fritche for 1842.5, is the same as Fritsche's for the earlier epoch! As is well known, Schmidt not only took into account the spheroidal figure of the Earth, but also, for the first time, treated the three components *X*, *Y*, *Z*, separately, so as to avoid, *ab initio*, the assumption that the entire effect was to be ascribed to a potential due solely to internal forces. He obtained a small potential due to external forces and a system of vertical electric currents. His computed components are the combined effects of the three system of forces thus found.

We are apparently forced to conclude that the 1885 charts may not represent any improvement on those for 1840–1845. If this be true, then the explanation is to be found in the following statement: The additional material obtained since the construction of Sabine's charts, has been mostly in regions of which the *general* magnetic distribution, as given on a chart, was already fairly well-known. For the most important areas, such as ocean areas, but comparatively little material has been obtained. Sabine's charts were based on data distributed over about seven decades, the epoch 1840–1845 being about midway in this interval, so that the reductions to epoch, because of secular variation were partly positive and

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TABLE G. Declination and inclination residuals for 1842.5 and 1885, according to Fritsche. ($D_o - D_c$ or $I_o - I_c$).

λ E of Gr	DECLINATION.														INCLINATION.												λ E of Gr
	60° N.		40° N.		20° N.		Equator.		20° S.		40° S.		60° S.		60° N.		40° N.		20° N.		Equator		20° S.		40° S.		60° S.		
	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	1842.5	1885	
°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
0	−1.3	+0.2	0.0	+1.1	−0.3	+1.8	−0.2	+1.1	−1.2	−0.4	+0.1	+0.3	−0.1	− 0.4	−0.3	−0.9	+0.5	+0.3	+1.7	−1.1	−0.2	−2.2	+0.4	+1 2	+0.7	+0.4	+0.2	−0.7	0
15		−0.9		−0.6		+0.2		+0.6		−0.2		−0.4		− 1.1		−1.4		0.0		−1.6		−2.2		+0.8		+1.5		−1.2	15
30	−0.5	−0 5	−1.4	−1.1	−1.0	−1.1	−0.4	−0 4	−0.8	−0.4	−0.9	−1.1	−1.8	− 0.7	−0.4	−1.4	+1.2	−0.6	−1.6	−1.1	−0.8	−1.9	−1.1	−0.1	−0.1	+1.5	−0.5	−0.8	30
45		0.0		−0.4		−1.1		−0.8		−0.5		−1.3		− 0.3		−1.2		−0.9		−0.7		−0.2		−0.8		+1.3		−0.7	45
60	+1.4	+1.0	−0.1	+0.6	−0.9	−0.7	−0.8	−0.3	+0.9	+0.2	+2.2	−0.7	+0.6	− 0.8	−0.8	−1.4	+0.5	−0.8		−0.8	+1.0	+0.2	+1.6	−0.6	+0.3	+1.0	−0.3	−0.5	60
75		+1.4		+1.2		−0.5		−0.5		−0.4		−0.8		− 2.6		−1.4		−1.0	+0.2	−1.1		+0.1		− 0.2		+0.8		−0.6	75
90	+1.3	+0.3	−1.7	+1.7	−0.6	+0.2	−0.4	+0.2	−0.2	−0 3	−1.8	−0.3	−0 4	− 2.7	−0.1	−1.6	−0.4	−1.2		−0.7	+0.8	−1.4	+1.2	−0.5	+0.2	+1.0	−0.2	−0.6	90
105		−0 4		+0.6		+1.1		+0.9		+0.5		+0.3		+ 4.2		−1.8		−1.3	−0.4	−0.6		−0.7		−0.3		+1.2		−0.8	105
120	−1.7	+0.5	−1.5	−0.2	+0.1	+0.5	+0.3	+0.9	−0.5	+1.0	+0.5	+1.8	+9.1	+10.3	−0.1	−1.6	0.0	−0 8		+0.2	+0.8	−0 1	+1.5	−0.7	−0.4	+1.3	−0.7	−0.2	120
135		−0.4		−0.9		+0.2		+0.2		+0.5		+0.3		+ 6.6		−1.1		−0.4	−0.1	+0.6		+0.6		+0.1		+0.9		+0.3	135
150	+0.9	−0.4	−1.0	+0.1	−0 1	+0.3	−0.2	+0.3	+0.7	+0.1	+0.4	−1.2	−0.2	+ 0.1	−0.2	−1.1	+1.4	−1.0		−0.5	0.0	+0.3	+0.3	0.0	−0.4	+0.6	+0.4	+0.5	150
165		+0.7		+0.7		+0.2		+0.4		−0.4		−1.7		− 0.2		−1.0		−1.4	+0.3	−2.7		−0.2		+1.0		+0.1		+0.6	165
180	+3.3	+1.3	−0.2	+1.0	−0.2	−0.2	−0.9	+0.1	−0.7	−0.9	−0.3	−1.8	−2.0	− 1.6	−0.2	−1.2	−0.5	−1.5		−3.8	+3.1	−0.9	+3.3	+0.3	+0.1	−0.5	+0.1	+0.2	180
195		+0.4		−0.7		−0.9		−0.2		−0.6		−1.3		− 2.5		−0.8		−1.5	−1.4	−2.3		−0.5		+0.5		−0.2		−0.2	195
210	+0.8	−1.5	+0.8	−0.9	+0.5	−0.4	+1.3	−1.2	−0.3	−0.3	−0 5	−0.3	−2.9	− 3.1	+0.4	−0.5	−0.8	−1.5		−0.8	−1 9	−0.3	+0.2	−0.4	+0.1	−0.5	+0.2	−0.2	210
225		−2.5		−0.6		−0.2		−1.7		−0.2		−0.1		− 3.4		−0.5		−1.3	−0.2	+0.7		−0.3		−0.7		−0.2		−0.5	225
240	−0.7	−2.5	0.0	−0.6	−0.9	−0.8	−0.9	−2.1	+0.4	−0 3	−0.3	−0.9	−3.0	− 3.2	+0.2	−0.4	0.0	−0.4		+0.8	−0.2	−0.3	+0.5	+0.5	−0.1	−0.2	+0.6	−1.1	240
255		−3 4		+0.1		−1.0		−1.3		−0.5		−1.4		− 2.0		−0 6		−0 7	0.0	+0.1		−0.3		+1.0		−0.5		+0.1	255
270	−3.0	−3.5	+0.5	+0.1	+0.1	−0.7	−0.3	+0.1	+0.9	−0.3	+1.1	−0.5	+0.4	+ 1.2	−0.1	−0.7	+0.4	−0.9		−0.8	+0.6	+0.2	−0.4	+1.6	+0.4	−0.8	0.0	−0.2	270
285		+3 9		+0.5		−0.1		−0.6		−1.0		−0.9		+ 1.7		−0.3		−1.1	−0.4	−1.0		−0.5		−0.2		−0.5		+0.6	285
300	−1.3	+1.3	−1.4	+0.1	−0.4	+0.7	−0.8	−0.2	−0.8	−1.5	+0.2	−0.9	−1.3	+ 0.7	0.0	−0.2	+1.0	−0.6		−0.7	+0.5	−0.1	+2.6	−0.4	−0.4	0.0	+0.2	+1.6	300
315		0 0		+0.5		+0.7		+0.2		−0.0		−0.3		+ 0.3		−0.1		−0.2	−0.2	+0.4		+0.4		−0.8		−0.3		+1.3	315
330	+0.4	−0.5	+2.2	+0.3	+0.4	−1.1	+0.9	−1.6	+0.8	−0.2	+0.3	+0.5	+0.3	+ 0.4	−0.4	−0.2	−0.2	−0.1		+0.8	0.0	−0.3	0.0	+1 4	−0.1	−1.2	+0.9	+0.2	330
345		−0.5		+1.1		+1.1		−0.8		−0.5		+1.1		+ 0.1		−0.4		0.0	+0.4	+0.8		−0.5		+3.4		−0.6		−0.4	345
Mean	1.4	1.2	0.9	0.65	0.5	0.7	0.6	0.7	0.7	0.5	0.7	0.8	1.8	2.1	0.3	0.9	0.6	0.8	0.6	1.0	0 8	0.6	1.1	0.7	0.3	0.7	0.4	0.6	Mean
Prob. Error	±1.2	± 1.0	±0.8	± 0.5	±0.4	± 0.6	±0 5	± 0.6	±0.6	± 0.4	±0.6	± 0.7	±1.5	±1.8	±0.2	± 0.8	±0 5	± 0.7	±0.5	± 0.8	±0.7	± 0.5	±0.9	± 0.6	±0.2	± 0.6	±0.3	± 0.5	Prob. Error

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partly negative, and thus the errors in reductions, to a certain extent eliminated. Neumayer, on the other hand, was obliged to depend entirely upon data accumulated up to the epoch 1885, his charts having been constructed in 1887. Hence, for large areas, he was forced to utilize data observed one-half century prior to his date and refer them to 1885, with more or less uncertain values of the secular change.

Another fact which leads one to conclude that in some manner an arbitrary or systematic error crept into the 1885 charts, due, possibly, to the reason stated, is the systematic variation in the probable errors with latitude. This will be noticed by looking over the X and Z figures in part II of Table D; it will be seen that the probable errors systematically increase with increasing latitude, whether we proceed north or south of the equator. This peculiar variation with latitude is not shown by the figures for either 1829, 1830, or 1842.5.

Let us pass next to the two bottom rows (Nos. 6 and 7) of Table F. Row No. 6 gives the probable errors resulting from the residuals between Schmidt's computed components and those of Fritsche. By glancing over the $S\,F$ residuals in Tables A, B, C, it will be seen that the results of the two computations often diverge more from each other than the results of either differs from the chart values, taken as standard of comparison. The average probable error of the total force resulting from these residuals is ± 73, hence, about the same as that of Schmidt's for 1885, and Fritsche's for 1842.5.

If we take as the computed components, the mean values of Schmidt's and Fritsche's computations, and compare the quantities thus derived with the chart values, then the residuals and probable errors will be materially reduced, as the two computations frequently diverge from the chart in opposite directions. See Part III, Table D, and row 7 of Table F. We now have probable errors about ten times those of field observations with modern instruments, and which probably represents the limit of accuracy attainable by a mathematical analysis based on general magnetic charts.

It is extremely unfortunate that we can not complete Table F, by including the probable errors resulting from the analyses of Adams for 1842.5, and for 1880. It is curious to note, by turning back to section a, Table V, that the value of the Earth's magnetic energy, as obtained from Adams' analysis for 1880, based upon Creak's charts, falls about midway between the values obtained

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from the Fritsche and Schmidt's analyses. The mean value of the principal coefficient, g_{10} is 0.31684 as derived from the Fritsche–Schmidt analyses, or precisely equal to that of Adams's for 1880. So that the impression is awakened that Adams' computed components might be found to lie between those of Fritsche and Schmidt, and hence that the probable errors for Adams' analysis might be on the order of those in row 7, of Table *F*, or in any event, be smaller than either those of Fritsche or Schmidt. I trust to be able to look into this matter more fully at some future date. Adams did not compute the components.

Looking at the probable errors in declination and in inclination (rows 3 and 4 of Table *F*), for 1842 and 1885, we again note that there has been no improvement for the later date, although Fritsche based his later analysis upon twice the number of points used in the earlier one.[1]

Having now obtained a good idea of the magnitude of the residuals to be expected between the computed quantities and the values based upon general, or terrestrial magnetic charts, let us next make a comparison of the declinations derived from the Schmidt analysis for 1885, and those scaled from the recently published isogonic chart of the United States for 1902. On this chart the isogonic lines, while still to some extent generalized, were drawn to conform as nearly as possible, with the large mass of data utilized. Restricted local disturbances, could of course, not be represented, however, areal and regional disturbances manifest themselves in manifold sinuosities in the curves. The scaled values for 1902.0 were referred to 1885.0, with the aid of fairly well-known secular changes.

Table *H* gives the results of the comparison. The residuals range from 2′ to 3°03′; the average residual, regardless of sign is 86′ from which the probable error of ± 72′ is derived. Table I gives a comparison of the Schmidt and Fritsche residuals, at eighteen points in the United States. The *F* residuals are in general smaller than the *S* ones, and of opposite sign, except for latitude 50° N., where the *F* residuals are very large.

Tables *G*, *H*, *I*, show sufficiently, that in refined work, as, for

[1] Judging from a remark attributed to Professor Schuster, when my paper on the Earth's total magnetic energy, was presented before the recent meeting of the British Association, he, apparently, has likewise made the discovery that the uncertainty in the potential computation has not been decreased for 1885; he is said to have found the uncertainty to be less for 1842.

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example, secular variation investigations, we can not, as has been proposed, make much use of the results obtained from a mathematical analysis. I shall have occasion to enter into this more fully in No. IV of these contributions.

TABLE H. Comparison of computed declinations according to Schmidt, and observed declinations in the United States for 1885.

λ W. of Gr.	30° N.			35° N.			40° N.			45° N.			50° N.			λ W. of Gr.
	D o	D c	D-D o c	D o	D c	D-D o c	D o	D c	D-D o c	D o	D c	D-D o c	D o	D c	D-D o c	
°	° ′	° ′	° ′	° ′	° ′	′	° ′	° ′	′	° ′	° ′	° ′	° ′	° ′	′	
65										−20 00	−17 39	−2 21				65
70							−10 50	− 8 28	−2 22	−15 50	−13 19	−2 31				70
75				− 3 20	− 1 58	−1 22	− 6 35	− 4 47	−1 48	−11 30	− 8 45	−2 45				75
80	+ 1 25	+ 2 24	−0 59	− 0 10	+ 0 51	−1 01	− 2 05	− 1 15	−0 50	− 4 30	− 4 12	−0 18				80
85	+ 4 05	+ 4 23	−0 18	+ 2 30	+ 3 22	−0 52	+ 2 20	+ 2 02	+0 18	+ 0 35	+ 0 12	+0 23	− 1 20	− 2 35	+1 15	85
90	+ 6 05	+ 6 03	+0 02	+ 6 15	+ 5 34	+0 41	+ 5 35	+ 5 01	+0 34	+ 5 50	+ 4 17	+1 33	+ 6 15	+ 3 12	+3 03	90
95	+ 7 50	+ 7 25	+0 25	+ 8 20	+ 7 30	+0 50	+ 9 45	+ 7 41	+2 04	+10 20	+ 8 00	+2 20	+11 30	+ 8 28	+3 02	95
100	+10 00	+ 8 33	+1 27	+11 00	+ 9 09	+1 51	+12 20	+10 02	+2 18	+13 40	+11 17	+2 23	−15 40	+13 04	+2 36	100
105	+11 00	+ 9 29	+1 31	+12 50	+10 35	+2 15	+14 30	+12 05	+2 25	+16 05	+14 07	+1 58	+19 20	+16 54	+2 26	105
110	+12 10	+10 15	+1 55	+14 00	+11 49	+2 11	+15 55	+13 52	+2 03	+18 25	+16 31	+1 54	+21 55	+20 01	+1 54	110
115	+11 45	+10 54	+0 51	+14 30	+12 53	+1 37	+16 50	+15 23	+1 27	+19 30	+18 29	+1 01	+23 45	+22 24	+1 21	115
120	+12 20	+11 28	+0 52	+15 20	+13 48	+1 32	+16 55	+16 38	+0 17	+20 10	+20 02	+0 08	−24 00	+24 07	−0 07	120
125							+17 45	+17 37	+0 08	+21 05	+21 09	−0 04	+24 10	+25 13	−1 03	125

TABLE I. Comparison of declination residuals resulting from subtracting computed declinations (Schmidt's and Fritsche's) from observed values in the United States for 1885.

λ W of Gr.	30° N.		35° N.		40° N.		45° N.		50°	
	S	F	S	F	S	F	S	F	S	F
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
75			−1 22	−0 01	−1 48	−0 10	−2 45	−0 45	+3 02	− 5 56
90	+ 0 02	−0 29	+0 41	−0 08	+0 34	−0 31	+1 33	+0 11	+1 54	+17 13
105	+ 1 31	−0 30	+2 15	−0 02	+2 25	−0 07	+1 58	−0 49	−1 03	+ 4 12
120	+ 0 52	−0 50	+1 32	−0 04	+0 17	−1 08	+0 08	−1 09		

The general conclusion to be drawn from the foregoing paragraphs, emphasizes once more,—as in section *a*—the absolute necessity of a new mathematical analysis, dependent upon a critical discussion and reduction of strictly homogeneous material.

TWO POINTS OF THEORETICAL INTEREST.

There may be two directions in which the Gaussian theory[1] will warrant modifications, in addition to those introduced by Schmidt.

First. The principal terms in the Gaussian analysis, arise from sufficiently deep-seated systems of forces, so that the magnetic per-

[1] What is meant by the Gaussian theory, and what physical facts it implies, are set forth in my article, *T. M.* Vol. V, p. 85.

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meability of the medium or material intervening between the seat of the systems and the points of observation on the Earth's surface, may have to be taken into account if further refinement in the analysis is to be attempted. We shall then have the generalized Laplacian equation:

$$\frac{\partial}{\partial x}\left(\mu\frac{\partial V}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu\frac{\partial V}{\partial y}\right)+\frac{\partial}{\partial Z}\left(\mu\frac{\partial V}{\partial z}\right)=0$$

in which μ is the magnetic permeability; it is no longer a constant as for the case treated in section *a*.

The magnetic distribution will now not be entirely harmonic.

Second. There is a possibility that there may be a minor system of forces so near the surface, that we can not any longer treat the points of observation on the Earth's surface, as though they were entirely outside the system of effective forces, so that the strict fulfillment of even the ordinary Laplacian equation—the fundamental property of a harmonic distribution—may not take place.

The detailed examination of these points must be reserved for the future.

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BESCHREIBUNG DES NEUEN MAGNETISCHEN THEODOLITEN, "BAMBERG" NR. 7904, AM MAGNETISCHEN OBSERVATORIUM IN POLA.

VON K. u. K. CORVETEN-CAPITÄN W. KESSLITZ.

Die nachstehenden Figuren 2 und 4 stellen die beiden von einander unabhängigen Theile des Theodoliten, nämlich das Instrument zur Winkelmessung und den Apparat für die Bestimmung der Schwingungsdauer in perspectivischer Ansicht dar.

Das Instrument wurde von der Firma Carl Bamberg in Friedenau bei Berlin gebaut, wobei der Normal-Theodolit in Potsdam als Modell gedient hat und verschiedene Verbesserungen nach den Angaben des damaligen Leiters vom magnetischen Observatorium, Professor Dr. M. Eschenhagen, angebracht worden sind.

Leider hat Professor Eschenhagen die Finalisierung dieses Theodoliten nicht mehr erlebt. An dem herben Verlust, welchen das k. preussische meteorologische Institut durch das am 12. November 1901 erfolgte Hinscheiden dieses unermüdlichen Forschers erfahren hatte, nimmt auch das k. u. k. Hydrographische Amt, dem der Verblichene in erdmagnetischen Arbeiten stets ein treuer Rathgeber gewesen war, den wärmsten Antheil.

1. THEODOLIT FÜR DIE WINKELMESSUNGEN.

Das sehr solid gebaute und noch durch einem 4 *cm* hohen Messingreifen verstärkte Dreifuss-Stativ *D* (Fig. 1) ruht mit den 3 klemmbaren Stellschrauben auf dem am Pfeiler aufgegypsten Unterlagskreuz. Die säulenförmige Büchse *B* der Alhidaden-Achse *A*, welche die Unterlage des oberen drehbaren Theiles bildet, ist am centralen Ring des Dreifusses festgemacht. Im Hohlraume dieses Ringes, an der Achsenbüchse mit 6 Kopfschrauben befestigt, befindet sich der Messingkörper *M*, welcher oben eine cylindrische Ausnehmung für die Pfanne *p* besitzt. Letztere wird durch 2 Stifte *s* geführt und kann mittels der Schraube *T* mit ränderiertem Kopfe gehoben und gesenkt werden. Indem die Alhidaden-Achse *A* mit dem am unteren Ende befestigten, abgerundeten Stein *a* in einer Mulde der Pfanne *p* aufruht, wird durch entsprechendes Anziehen der Schraube *T* die Entlastung der Achse bewerkstelligt.

Die Schraubenmutter *m* bildet die Befestigung der Alhidaden-Achse in der Büchse; um erstere herauszuheben, muss vorerst die Schraubenmutter nach Abnahme des Messingkörpers *M* und der Pfanne *p* abgeschraubt werden.

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Auf dem Ringansatz *r* der Achsenbüchse ist der Kreis *K* aufgesteckt, der sich aus 2 concentrischen, durch 6 Speichen verbundenen Ringen zusammensetzt. Indem der mit 4 Schrauben befestigte Deckring *d* den konisch geführten inneren Ring des Kreises nach unten presst, wird an der Berührungsfläche des letzteren genügend Reibung erzeugt, so dass eine Verdrehung des Kreises nur mit grösserem Kraftaufwande möglich ist.

Der silberne Limbus besitzt einen Durchmesser von 272 *mm* und ist von 5 zu 5′ getheilt. Eine zweite Theilung in halbe Grade befindet sich am inneren Rande des Kreisringes und dient zur Einstellung des Kreises auf den Index, der auf einem vom Deckringe *d* ausgehenden und bis zum äusseren Kreisringe reichenden Messingzeiger eingeritzt ist.

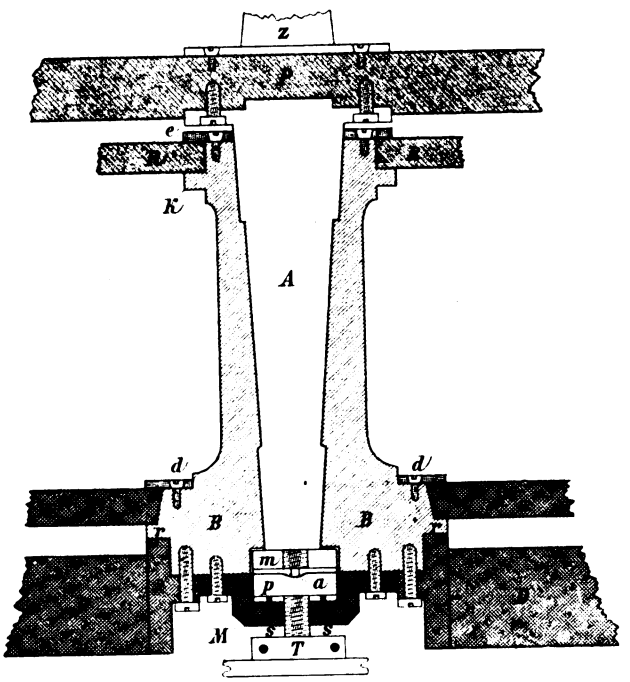

FIG. 1. (⅓ Natürliche Grösse.)

Am Ringansatz *k* der Achsenbüchse ist die Klemmplatte *R* mit der Klemmvorrichtung und der Mikrometer-Schraube sammt Federbüchse aufgesteckt und durch einen an der Büchse mit 4 Schrauben befestigten Deckringe niedergehalten. Diese Bestandtheile zeigen keine Abweichungen von den sonstigen Constructionen und ist deren Einrichtung aus Fig. 2 zu ersehen.

Das obere Ende des Achsen-Konus ist in die zum Theil durchbrochene,

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im Centrum 22 *mm* dicke Alhidaden-Platte *P* eingelassen und dessen Ringverstärkung mit 6 Schrauben daran befestigt. Im Centrum der Alhidaden-Platte ist auf der Oberseite der konische Zapfen *Z* vom Magnetgehäuse festgemacht. Letzteres (Fig. 2) besitzt eine ähnliche Einrichtung wie beim neuen magnetischen Unifilar-Theodoliten von H. Wild[1] und besteht aus einem ringförmigen Gussstücke aus Messing, welches mit einer Hülse am centralen konischen Zapfen der Alhidaden-Platte aufgesteckt ist. Zur Orientierung des Gehäuses und der daran befestigten zweitheiligen Ablenkungsschiene ist am unteren Ende der Hülse ein drehbarer Ring angebracht, von dem ein Ansatz zwischen zwei auf der Alhidaden-Platte situierte Justier-Schrauben zu liegen kommt. Die Verbindung von Ring und Gehäuse wird durch eine Druckschraube bewerkstelligt. Ist letztere gelüftet, so lässt sich das Gehäuse beliebig verdrehen; nach bewirkter Klemmung des Ringes geschieht sodann die feine Einstellung mittels der auf der Alhidaden-Platte befindlichen 2 Justier-Schrauben.

Zum Schutze der eingehängten Magnete gegen Luftströmungen werden die cylindrischen Holzdeckel (in Fig. 2 abgenommen und am Dreifuss-Stativ angelehnt) mit den auf der Innenseite befindlichen 3 *mm* dicken Messingringen in das Gehäuse eingeschoben, wobei die rundlichen Ausnehmungen am Rande des äusseren schwachen Messingringes die cylindrischen Köpfe der Befestigungsschrauben passieren. Durch eine kleine Drehung kommt dann der äussere Ring unter die Schraubenköpfe zu liegen und wird auf diese Weise der Deckel festgehalten. In der Mitte der Deckel sind cylindrische Holzansätze angebracht, deren Öffnungen durch planparallele Glasplatten geschlossen sind.

Um die pendelnden Bewegungen des Magnet-, beziehungsweise Torsions-Stabes zu beruhigen, ist im Magnetgehäuse eine Petroleum-Dämpfung angebracht. Ein 15 *mm* hoher Napf von 30 *mm* Durchmesser ruht hiezu am cylindrischen Kopf eines federnden Stiftes, der durch einen Excenter gehoben oder gesenkt werden kann. Die Excenter-Welle lagert in einer Durchlochung der Alhidaden-Platte und befindet sich ihre Handhabe mit ränderiertem Kopfe auf der linken Seite des Fernrohrträgers. Die Hubhöhe des Excenters beträgt 4 *mm*. Zur Führung des federnden Stiftes dient eine oben cylindrisch ausgenommene Schraubenmutter, welche in den Gehäuseboden eingeschraubt ist.[2]

In den Petroleumnapf taucht ein kreuzförmiger Messingflügel mit kreisrunden Durchlochungen, welcher mit einem Doppelhaken am unteren Tragstift des Magnets oder Torsions-Stabes eingehängt wird.

In den zwei seitlichen Tubulaturen des Gehäuseringes sind die konisch zulaufenden und eingeschliffenen Enden der Ablenkungsschienen

[1] Mémoires de l'académie impériale des sciences de St. Pétersbourg. VII^e série, tome XXXVI, Nr. 1.

[2] Es hat sich vortheilhaft gezeigt, den Petroleumnapf ein- für allemal in einer bestimmten Höhe eingestellt zu belassen.

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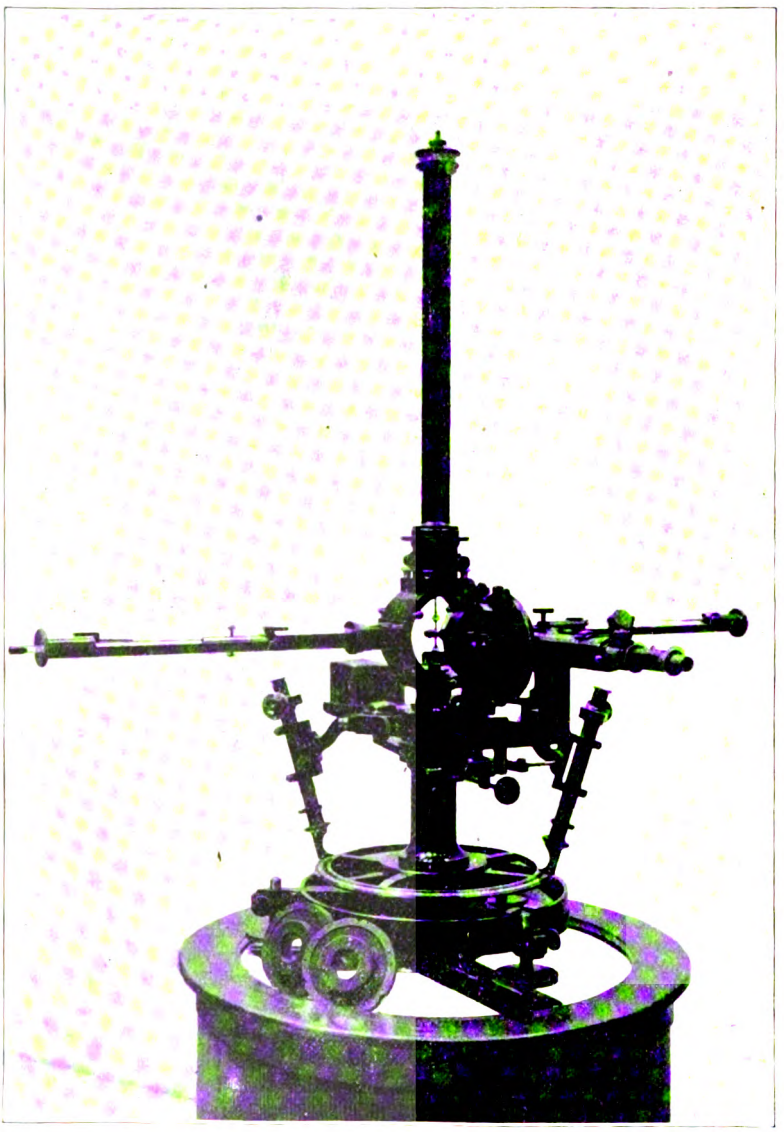

FIG. 2.

eingeschoben. Zur Erzielung einer unveränderlichen Stellung werden die Flanschen der Schienen mit den in Fig. 2 ersichtlichen grossen Schraubenmuttern an die oberen Ränder der Tubulaturen fest angepresst. Eine weitere Befestigung bewirkt noch eine Schraube mit versenktem

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Kopfe, die, durch die Tubulatur hindurchgehend, mit ihrer konischen Spitze in eine gleichgeformte Aushöhlung des konischen Rohransatzes der Schienen eingreift.

Von den röhrenförmigen Schienen ist die obere Hälfte auf eine längere Strecke abgenommen, so dass eine im Querschnitt halbkreisförmige Rinne entsteht, in welche der ablenkende Magnet (Schwingungsmagnet) eingelegt wird. Der äussere Durchmesser des Magnets entspricht genau dem inneren der Röhre. Zur Einstellung desselben auf einen bestimmten Strich der Schienentheilung, die sich auf der einen, gegen das Fernrohr gewendeten Flachseite der Ausnehmung befindet, ist in der Mitte der Magnetröhre ringsum ein feiner Strich eingerissen. Die Einstellung geschieht mit der Hand bei Benützung einer Lupe. Zur Erleichterung des Einstellens bei einer fix angenommenen Ablenkungs-Distanz benützt man einen Anschlag, d. i. es wird der Magnet mit der einen Endfläche an den abgeschliffenen Kopf einer Schraube angeschoben, die in der Achse der Rinne in einem am Schienenrohr befestigten Messingwinkel klemmbar eingeschraubt ist. Die gleiche Einrichtung befindet sich am anderen Ende der Schienenausnehmung für die Beobachtung in der grösseren Distanz bei Bestimmung der sogenannten Ablenkungs-Constante.[2]

Zur Messung der Temperatur des Magnets wird ein in $\frac{1}{5}°$ getheiltes Thermometer in die Höhlung der Schiene gelegt und mit seinem cylindrischen Gefäss in den Magnet eingeschoben. Eine entsprechend weite Cartonröhre, die über die Schiene aufgestülpt wird, hat den Magnet vor der Wärmeausstrahlung des Beobachters zu schützen.

Auf der Oberseite besitzt der Gehäusering eine quadratische Verstärkung mit kreisförmiger Durchlochung, in welche der abgedrehte Fuss des Suspensions-Rohres bis zu der dem Gehäuseobertheil conform gestalteten Flansche eingeschoben und durch 4 Kopfschrauben befestigt wird.

Das Suspensions-Rohr setzt sich aus 3 Theilen zusammen, dem Klemmgehäuse, dem Fadenbehälter und dem Torsions-Kopf. Der 44 *cm* lange Fadenbehälter, ein Messingrohr von 35 *mm* Durchmesser, ist am Klemmgehäuse aufgeschraubt und durch eine seitlich in die Gewinde eingreifende Schraube gegen Verdrehungen versichert.

Die Klemmvorrichtung besteht aus der in Fig. 3 skizzierten Excenter-Scheibe *S*, welche auf die Stiftansätze *e* der Klemmplatten *K* einwirkt, und den seitlich im Klemmgehäuse angeschraubten Federbüchsen *F* für die Achsen *a* der Klemmplatten.

Die Bewegung der Excenter-Scheibe geschieht durch einen an der Verbindungsstelle zwischen Gehäuse und Fadenbehälter drehbar aufgesteckten, ränderierten Messingring, der mittels einer Schraube, welche

[2] Diese Anschlags-Einrichtung hat sich insoferne als illusorisch gezeigt, als die beiden Schwingungsmagnete nicht genau die gleiche Länge besitzen, daher bei jeder Bestimmung der Ablenkungswinkel die Anschlagschrauben verstellt werden müssen.

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in einem Spalt des Gehäuses geführt wird, mit der Excenter-Scheibe in fester Verbindung steht. Durch ½ Umdrehung des Ringes nähern sich die Stiftansätze *e* und werden damit die Klemmplatten fest an den Rahmen *R* des Fadenbügels angedrückt. Bei der Rückdrehung kommen die in den Federbüchsen eingelagerten Spiralfedern, die sich einerseits an die Schraubenköpfe *k* am äusseren Achsenende, anderseits an den inneren Absatz der Führungshülsen *f* der Achsen stützen, zur Wirkung: die Achsen mit den daran befestigten Klemmplatten werden zurückgezogen und damit die Klemme geöffnet.

Um eine Verdrehung der Achsen und damit ein Heraustreten der Stifte aus der Excenter-Scheibe zu verhindern, besitzen die Achsen seitliche Dornansätze, welche in einer entsprechenden Nuth der Führungshülsen laufen. Die Achsen der Klemmplatten sind ferners der Länge nach durchbohrt und ist am äusseren Ende der einen Achse ein durchgehender Stift *t* angeschraubt, welcher, die breite Öse des Fadenbügels durchdringend, eine Verdrehung des letzteren zu verhindern hat.[1]

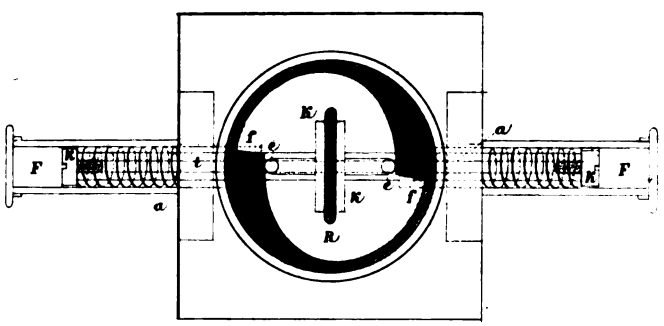

FIG. 3. ($^2/_3$ Natürlicher Grösse.)

Der Torsions-Kreis, welcher mit einem konischen Zapfen fest verbunden ist, besitzt eine Theilung von 5 zu 5°. Durch die centrale quadratische Durchlochung desselben geht der unten prismatisch geformte, oben mit Schraubenwindungen versehene Fadenträger hindurch, dessen verticale Verschiebung durch eine sich am Torsions-Kreis aufstützende Schraubenmutter mit ränderiertem Kopfe bewirkt wird. Der konische Zapfen ist in einem kurzen Cylinder eingepasst, der in das Suspensions-Rohr eingeschoben und durch einen Stift gegen seitliche Verdrehung gesichert wird. Zwischen dem oberen Ringansatz dieses Cylinders und dem Torsions-Kreis ist ein letzterem conform gestalteter Ring mit Index aufgelegt.

[1] Bei einem Theodoliten mit fixer Aufstellung scheint mir eine derart eingerichtete Klemmvorrichtung wohl gänzlich überflüssig, da der Faden auch ohne Klemmung durch ein entsprechendes Torsions-Gewicht stets in gleichmässiger Spannung erhalten werden kann.

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Von den beiden seitlichen Arretierungs-Schrauben ist die mit ränderiertem Kopfe zur Fixierung des Torsions-Kreises bestimmt, indem die Spitze dieser Schraube in die Ringnuth des konischen Zapfens eindringt und angezogen auf letzteren drückt. Bei der zweiten Schraube ist die Tiefe des Eindringens in die Ringnuth durch einen cylindrischen Ansatz am Schraubenkopf begrenzt. Lehnt sich dieser Ansatz an das Suspensions-Rohr, so ist die Spitze der Schraube zwar auch in die Ringnuth eingetreten, berührt aber den Konus nicht. Es kann dann letzterer und damit auch der Torsions-Kreis zwar gedreht, nicht aber aus dem Suspensions-Rohre herausgezogen werden. Zur Befestigung des Metallfadens ist vom unteren Ende des prismatisch gestalteten Fadenträgers ein 10 *mm* langes Stück unter einem rechten Winkel herausgeschnitten und mittels Präcisions-Stift und Schräubchen befestigt. Der Faden wird zwischen diesen beiden Theilen des Trägers geklemmt und läuft dann durch eine schräge Durchlochung nach aussen, wo er an einem kleinen Schräubchen mit Unterlagsplättchen festgemacht ist. Eine gleiche Klemmung befindet sich am oberen Ende des Fadenbügels. Letzterer besitzt unter der Fadenklemme einen kreisrunden, abgedrehten Rahmen, der zwischen die Klemmplatten zu liegen kommt. Unten ist ein 63 *mm* langer Stift mit einem Doppelhaken zum Einhängen des Magnets angebracht.

Als Aufhängefaden für den Declinations- und Torsions-Stab, sowie für die abzulenkende Nadel dient, wie beim Normal-Theodoliten in Potsdam, ein 0.04 *mm* dicker Messingdraht.[1]

Auf dem einen Ende der länglich gestalteten Alhidaden-Platte ist der ⊔-förmige Fernrohrträger befestigt, am anderen Ende ein mit Blei ausgegossener Messing-Cylinder als Gegengewicht aufgeschraubt. In die senkrechten Arme des Fernrohrträgers sind die halbcylindrischen Lager der Achsenzapfen vom Fernrohr ausgeschliffen und letztere durch mit Kopfschrauben befestigte, gleichfalls ausgeschliffene Messingdeckel abgeschlossen. Am linken Achsenzapfen ist der Vertical-Kreis befestigt und die Nonius-Platte aufgesteckt, deren unterer Ansatz durch einen federnden Stift gegen die Spitze der Nonius-Rectificierschraube gedrückt wird. Die Theilung am Limbus des Vertical-Kreises geht auf halbe Grade, der Nonius ermöglicht eine Ablesung auf ganze Minuten. Der Träger für die Nonius-Lupe ist gleichfalls am linken Zapfen aufgesteckt.

Die Klemmvorrichtung des Fernrohres besteht aus einer Platte, deren unterer Ansatz zwischen der Mikrometer-Schraube und dem Stift der Federbüchse gelagert ist. Die Klemmschraube drückt von oben auf den Achsenzapfen und stellt, angezogen, eine feste Verbindung des Fernrohres mit der Klemmplatte her.

Da sich die Fernrohrachse ziemlich nahe dem Objectiv befindet, ist

[1] Das erdmagnetische Observatorium in Potsdam hat dem k. u. k. Hydrographischen Amte eine Rolle des dort benützten Messingdrahtes freundlichst zur Verfügung gestellt.

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an der Fassung des letzteren ein cylindrisches Gegengewicht angebracht. Das Objectiv besitzt eine Öffnung von 32 *mm*. Das umlegbare Fernrohr ist terrestrisch eingerichtet und befindet sich die mit seitlichen Schrauben verstellbare Fadenplatte im Ocular-Auszug vor dem ersten Linsenpaar, also zwischen Objectiv und Ocular eingesetzt.

Unmittelbar hinter der Fadenplatte ist eine um 45° geneigte, planparallele Glasplatte eingesetzt, von der die untere Hälfte Spiegelbelag besitzt.[1] Zur Beleuchtung des Fadenkreuzes ist oberhalb der Glasplatte im Ocularrohr ein kreisrundes mit einer planparallelen Glasscheibe geschlossenes Loch ausgeschnitten und darüber ein universal drehbarer, runder Beleuchtungsspiegel angebracht.

Der Ocular-Auszug besitzt die sogenannte pankratische Einrichtung, d. h. es sind die das Ocular bildenden zwei Linsenpaare durch Einschaltung eines zweiten Auszuges sowohl gegen einander als auch zusammen gegen das Fadenkreuz verstellbar, wodurch innerhalb bestimmter Grenzen eine Variation der Vergrösserung zulässig ist.

Die Bewegung des ganzen Ocular-Auszuges geschieht mittels Welle und Zahnstange. Zur Führung der letzteren ist am Objectivrohr ein Plättchen mit rechteckigem Ausschnitt aufgeschraubt, in welchen die Zahnstange genau hineinpasst. Da die Schraubenlöcher im Plättchen länglich gestaltet sind, lässt sich die Zahnstange und damit auch der Ocular-Auszug sammt Fadenplatte behufs Justierung des Fadenkreuzes um ein Geringes verdrehen.

Die Ablesung der Alhidaden-Stellung geschieht mittelst Mikroskope, deren Träger, wie aus Figur 2 ersichtlich ist, an entsprechenden Ansätzen der Alhidaden-Platte festgeschraubt sind. Das Mikroskop *A* befindet sich rechts vom Fernrohr in einem Winkelabstand von 45°, ihm gegenüber ist das Mikroskop *B* angebracht. Jede Trommelumdrehung bewirkt eine Verschiebung des Doppelfadens um einen Theilstrich am Limbus, das sind 5′. Die rechteckig ausgeschnittene Blende besitzt in der Mitte einen zahnförmigen Einschnitt als Index. Da die Trommeleintheilung 100 Striche besitzt, können 5″ direct abgelesen und auf 1″ geschätzt werden. Zur Beleuchtung des Limbus sind zwar am Objectivende der Mikroskope Gipseinsätze drehbar angebracht, es wird jedoch eine scharfe Belichtung nur bei Anwendung eines kleinen Hohlspiegels erzielt, dessen Handhabung übrigens keinen nennenswerten Zeitverlust mit sich bringt.

Neben dem Träger vom Mikroskop *B* ist auf der Alhidaden-Platte eine kleine Dosenlibelle aufgeschraubt.

Die zu den Messungen dienenden Magnete, das sind der Declinations-Magnet, der kleine abzulenkende Magnet und die beiden gleichen Schwingungsmagnete I und II wurden aus Phönix-Wolfram-Stahl von

[1] Bei Einlieferung des Instrumentes hatte die Glasplatte keinen Spiegelbelag und gab deshalb nur sehr undeutliche reflectierte Bilder des Fadenkreuzes.

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der Firma Joh. E. Bleckmann in Mürzzuschlag erzeugt und nach der Methode von Strouhal und Barus magnetisiert.

Sowohl der Declinations-Stab als auch die Schwingungsmagnete sind Röhren von 70.0 *mm* Länge, 10.5 *mm* äusseren und 6.5 *mm* inneren Durchmesser. Während bei den Schwingungsmagneten die Spiegel auf die ringförmige Endfläche am Nordende aufpoliert sind, wurde beim Declinations-Magnet ein runder, in einem kurzen Messingröhrchen gefasster Glasspiegel eingefügt und am Südende ein entsprechendes Gegengewicht angebracht.[2]

Das Gewicht der Schwingungsmagnete beträgt 29.15 *g*, jenes vom Declinations-Magnet 29.42 *g*.

Für das vorgenannte Dimensions-Verhältnis bei den Schwingungsmagneten hatte man sich deshalb entschieden, weil einerseits Professor Eschenhagen mir gegenüber die Dimensionen der Potsdamer-Magnete — nämlich Länge 75 *mm*, äusserer Durchmesser 16 *mm*, innerer Durchmesser 10 *mm* — für die Constanz des magnetischen Momentes nicht für zweckmässig bezeichnet hatte und anderseits mit dünneren Magnetröhren (Dimensions-Verhältnis 1:7) bei Reisetheodoliten sehr gute Erfolge erzielt worden waren.

Der abzulenkende Magnet mit Glasspiegel am Nordende ist eine Stahlröhre von gleichem Durchmesser wie bei den Schwingungsmagneten und hat eine Länge von 32.7 *mm*. Letztere beträgte somit 0.467 der Länge der Schwingungsmagnete. Durch die Wahl dieser Längen-Dimensionen wurde nach Wild der Bedingung entsprochen, dass das Glied q in der Gleichung für die sogenannte Ablenkungs-Constante verschwindet.

Als Torsions-Stab wird endlich ein cylindrischer Magnetstab benützt, welcher, von einer Messingröhre mit Spiegel am Nordende eingeschlossen, etwa ⅓ des magnetischen Momentes vom Declinations-Magnet besitzt. Das Gewicht des Torsions-Stabes ist das gleiche wie jenes vom Declinations-Magnet.

Sowohl die Schwingungsmagnete als auch die abzulenkende Nadel besitzen auf der einen Seite die Buchstaben *N* und *A*, auf der anderen Seite *B* eingraviert. Das *N* befindet sich am Nordende der Röhre. Bei den Schwingungsmagneten ist noch die Bezeichnung I beziehungsweise II angebracht. Der Declinations- und Torsions-Stab besitzen zur Unterscheidung der beiden Spiegellagen die Bezeichnungen • und ••.

Zum Einhängen der Magnete in den Doppelhaken des Fadenbügels sind in der Mitte der Magnetröhre oben und unten je ein 10 *mm* langer T-förmiger Traghaken eingeschraubt, wobei der kurze horizontale Stift zur Magnetachse parallel gestellt ist.

[2] Die Anbringung eines Glasspiegels, beziehungsweise die Anwendung eines separaten Declinations-Magnets machte sich deshalb nothwendig, weil die angeschliffenen Spiegel der Schwingungsmagnete im Fernrohr des Theodoliten so schlechte Bilder vom Fadenkreuz gaben, dass eine scharfe Einstellung ganz unmöglich war.

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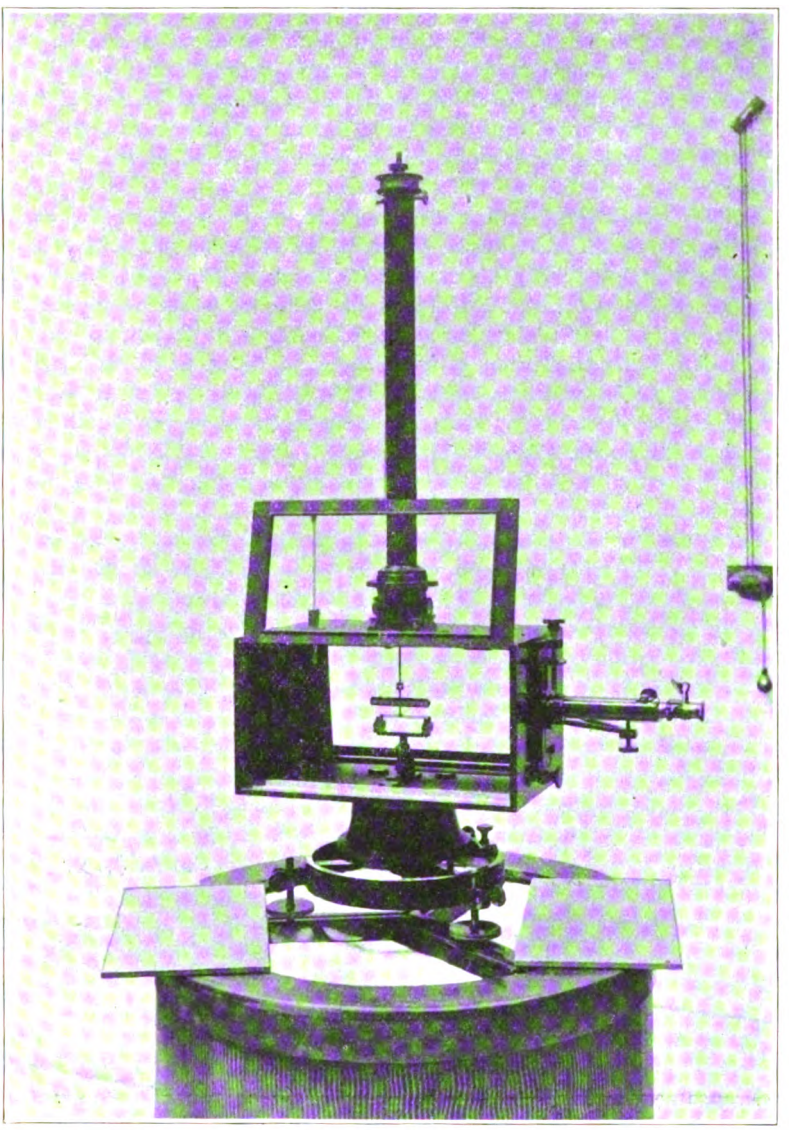

FIG. 4.

2. APPARAT ZUR BESTIMMUNG DER SCHWINGUNGSDAUER (FIG. 4).

Der Dreifuss mit den 3 klemmbaren Stellschrauben bildet mit dem 32 *mm* hohen Messingreifen, auf dessen abgedrehter Oberseite eine Eintheilung in halbe Grade eingerissen ist, ein Stück. In der konischen

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Durchlochung des centralen Ringes ruht der Alhidaden-Zapfen und ist derselbe durch eine Schraubenmutter ohne weitere Entlastungsvorrichtung festgemacht. Die Alhidaden-Platte besitzt 3 Arme, von denen der eine den Nonius mit Theilung von 2 zu 2′, der zweite die Klemm- und Mikrometer-Vorrichtung trägt und der dritte auf einem gegen den Kreis abgeschrägten Ansatz nur mit einem einfachen Index-Strich versehen ist.[1]

Auf der Alhidaden-Platte ruht ein cylindrischer 7 *cm* hoher Holzklotz, die Unterlage des Schwingungskästchens. Die Befestigung des letzteren geschieht, mittels 3 Schraubbolzen, welche, durch den Holzklotz hindurchgesteckt, unten mit ihren Köpfen in die Alhidaden-Arme eingelassen sind, während an den oben herausragenden Enden die Schraubenmuttern und Unterlagsscheiben aufgesteckt sind. Das parallelpipedische Kästchen aus Mahagoniholz besitzt eine Länge von 32, eine Breite von 21 und eine Höhe von 17.5 *cm*. Die Seitenwände werden durch nach oben zu aufklappbare Charnier-Deckel mit Glasfenster gebildet. Ausserdem sind noch die in Falzleisten verschiebbaren, in Fig. 5 herausgezogen abgebildeten Holzdeckel angebracht.

Der Fuss des Suspensions-Rohres sammt Klemmgehäuse, welches die gleiche Einrichtung zeigt, wie jenes vom Theodoliten, ist in die kreisförmige Durchlochung der in der Mitte am Kastendeckel mit 4 Holzschrauben befestigten quadratischen Platte eingeschoben und dann in gleicher Weise wie beim Theodoliten mit 4 Kopfschrauben festgemacht.

Auf der vorderen Gehäusewand befindet sich ein Messingrahmen, in dessen schwalbenschwanzförmige Nut der Fernrohrschlitten mittelst der aus Fig. 5 ersichtlichen, verticalen Mikrometer-Schraube verschiebbar ist. Das Fernrohr mit 17 *mm* Objectiv-Öffnung besitzt im Ocular-Auszug ein Glas-Diaphragma mit eingeritzter Scala und der gewöhnlichen Beleuchtungsvorrichtung, nämlich ein hinter der Scala eingesetztes dreiseitiges Prisma und darüber ein universal drehbaren Spiegel.[2]

Durch das Prisma wird der obere Theil des Gesichtsfeldes verdunkelt und ist nur dessen untere Hälfte mit dem durchgehenden Mittelstrich durchsichtig. Da sich die Achsenzapfen des Fernrohres nahe bei der Objectiv-Öffnung befinden, ruht ersteres auf der Elevations-Schraube, mit welcher ein Heben und Senken des Ocular-Endes bewirkt wird.

In der Mitte des Kästchens befindet sich noch ein als Arretiervorrichtung dienender Magnetträger. Das Heben und Senken der V-förmigen Lageransätze, die auf einer gemeinsamen rechteckigen Platte justierbar

[1] Ursprünglich war nur der Index-Strich (wie in Potsdam) vorhanden. Zur bequemeren Einstellung des Spiegelbildes und zur Winkelmessung bei Bestimmung des Torsions-Einflusses wurde nachträglich ein Nonius und die Mikrometer-Einrichtung vom Mechaniker Rost in Wien angefertigt.

[2] Wegen des directen Oberlichtes konnte der Beleuchtungsspiegel abgenommen werden. Die ursprünglich beigegebene Glasplatte hatte zu feine Striche und war daher das Spiegelbild sehr undeutlich, während das jetzt eingesetzte Diaphragma, ein Reservestück vom Theodolit Schneider, sehr gute Spiegelbilder liefert.

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befestigt sind, geschieht durch die nahe dem Kastenboden eingesetzte Welle, deren Zahnrad in das untere, mit einer Zahnstange ausgerüstete Ende des Plattenträgers eingreift. Die Führung des letzteren geschieht durch eine am Kastenboden mittelst Schrauben befestigte Messinghülse.

Auf der vom Fernrohr abgewendeten Seite ist noch am Kastendeckel ein Messing-Tubus zum Hineinstecken des Thermometers eingesetzt. Der Fadenbügel besitzt bis auf die etwas längere ovale Schlinge die gleiche Einrichtung wie jener beim Theodoliten und dient zur Aufhängung des Magnets ein 0.05 *mm* dicker Messingdraht, dessen Torsionskraft durch mässiges Erwärmen mit Hilfe eines starken Batteriestromes erheblich herabgemindert wurde.

3. Verification des Instrumentes.[1]

Eisenfreiheit. Sämmtliche Bestandtheile des Theodoliten und des Apparates zur Bestimmung der Schwingungsdauer wurden auf das sorgfältigste auf Eisenfreiheit geprüft, indem man Stück für Stück in unmittelbare Nähe des Magnetgehäuses vom Unifilar brachte, während ein Gehilfe den Stand der Scala vom Magnetspiegel beobachtete. Hiebei constatierte man, dass sowohl die Suspensions-Rohre, als auch die Ablenkungsschienen einen geringen Eisengehalt aufweisen und somit vom Mechaniker der an ein magnetisches Normal-Instrument zu stellenden Hauptanforderung — nämlich absolute Eisenfreiheit — nicht mit der nöthigen Gewissenhaftigkeit nachgekommen worden war. Diesbezügliche Anfragen wurden von der Firma C. Bamberg dahin beantwortet, dass die in Rede stehenden Bestandtheile zwar aus vollkommen eisenfreiem Material erzeugt worden waren, aber nach der Bearbeitung auf der Drehbank einen geringen Eisengehalt angenommen hatten.

Spuren vom Eisengehalt sind ferner noch in den Bronzestäben zur Bestimmung der Trägheitsmomente der Schwingungsmagnete aufgefunden worden.

4. Apparat zur Bestimmung des Inductions-Coefficienten nach der Weber'schen Methode.

Der hiezu vom Mechaniker Töpfer in Postdam construierte Apparat besteht aus einem 19 *cm* langen, mit circa 17 Lagen übersponnenen Kupferdraht von 0.25 *mm* Stärke umwickelten Messingrohr, welches in der aus Fig. 5 ersichtlichen Weise derart auf dem ⊔-förmigen Träger aufmontiert ist, dass mittelst einer Kurbel eine Drehung um die Horizontal-Achse ausgeführt werden kann.

Durch entsprechende Anschläge wird die Drehung der Spule auf genau 180° begrenzt. Die Achsenträger und die gemeinschaftliche Fussplatte sind auf einem gewöhnlichen Dreifuss-Stativ drehbar befestigt. Auf der Fussplatte kann eine Dosenlibelle oder eine Bussole zur Nivellierung, beziehungsweise Orientierung des Apparats aufgesteckt werden.

[1] For method of adjustment of instrument and report on determination of constants, see "Jahrbuch" Pola Observatory for 1902.—Ed.

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Die Drahtenden der Spule laufen von der Mitte aus durch den einen hohlen Achsenzapfen nach aussen zu den Klemmschrauben auf der Fussplatte. Die Umwicklung besitzt einen Widerstand von 121 Ohm.

Zur Bestimmung des Inductions-Coefficienten wurde das Instrument zunächst derart orientiert, dass die Vertical-Ebene, in welcher die Drehung der Spule erfolgt, mit dem magnetischen Meridian einen rechten Winkel bildete. Nach Anschliessung des hochempfindlichen Rosen-

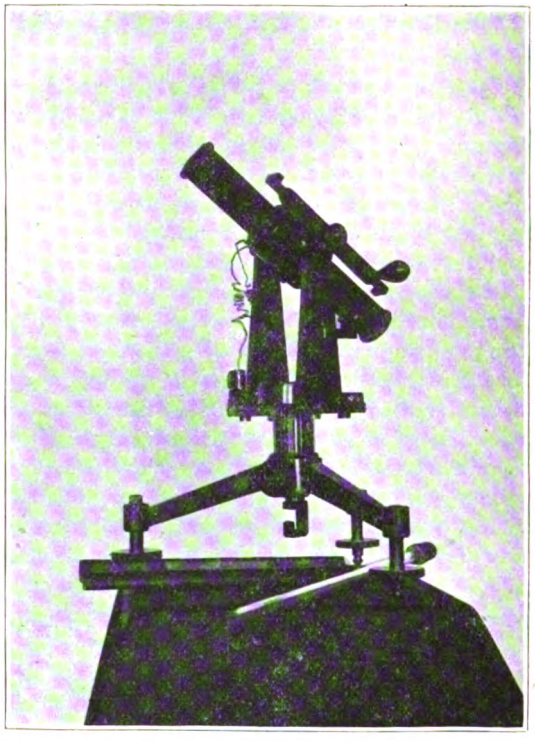

FIG. 5.

thal'schen Galvanometers, welches für die Inclinations-Bestimmungen benützt wird, wurde zuerst die Spule allein (10mal) und dann die Spule mit dem genau centrierten Magnet (40mal) um 180° gedreht.[1] Die Richtung der Drehung liess man hiebei abwechseln und wurde auch der Magnet in der Holzfassung umgelegt.

[1] Zur Centrierung des Magnets diente ein zweitheiliger, in die Spule genau hineinpassender Holz-Cylinder, in dessen Mitte eine den Dimensionen des Magnets entsprechende Ausnehmung ausgedreht worden war.

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Behufs Auswertung stellte man sodann die Spule vertical, schob ein 47 *cm* langes, in einem Holzpfropf eingepasstes Glasrohr,[1] welches unten abgeschlossen war, bis zur Hälfte in die Spule und liess einen kleinen Magnet von bekanntem Moment aus einer Höhe von 35 *cm* in die Glasröhre hineinfallen, beziehungsweise rasch herausziehen.

Vergleicht man die mit diesem Apparate erhaltenen Werte von k mit jenen nach der Methode von Lamont gefundenen, so zeigt sich eine überraschend gute Übereinstimmung und wurde daher ohne Bedenken das Mittel der so nach verschiedenen Methoden abgeleiteten Coefficienten für die Berechnung der Inductions-Correction verwendet:

	Magnet I	Magnet II
Inductions-Coefficient nach Lamont:	0.00957	0.00998
„ „ „ Weber:	0.00954	0.00992
Mittel:	0.00956	0.00995

[1] In Fig. 5 befindet sich das Glasrohr unter dem Stativ neben der rechten Stellschraube.

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THE LUNAR DIURNAL VARIATION AS OBTAINED AT THE CHELTENHAM MAGNETIC OBSERVATORY FROM A SINGLE COMPLETE LUNATION DURING FEBRUARY, 1903.[1]

By L. A. Bauer and R. E. Nyswander.

(Abstract.)

The attempt was made to determine how well the lunar diurnal variation of the magnetic elements could be determined from simply one complete lunation, instead of using records extending over a period of a year or more.

For this purpose the comparatively "magnetically calm" month of February, 1903, was selected and the photographic records obtained at the Cheltenham Magnetic Observatory of the Coast and Geodetic Survey with an Eschenhagen Magnetograph were utilized. The scale values used were: 1 mm. ordinate, declination = 1.014 minute,

1 mm. " horizontal intensity = 0.00002 C. G. S. unit.

The recently arrived vertical intensity instrument was not yet in satisfactory adjustment and hence the records could not be successfully used.

First the declination ordinates were read off at the actual lunar hours as marked on the magnetograms, for the entire lunation beginning on February 1, 1903, and tabulated in the same manner as are the solar ordinates for a calendar month. On February 7th occurred a disturbance of sufficient amount to require elimination. In place of the actually observed ordinates, the means of the corresponding hours of the two days between which the disturbance occurred were substituted. The mean ordinates for each lunar hour for the entire lunation were next derived and the residuals on the mean of all the ordinates formed; these residuals being freed by this process from the effect of the solar diurnal variation, since the same solar hour fell successively on each lunar hour, were expected to exhibit the lunar diurnal variation in the declination. How well they do so, is seen by an inspection of the curve drawn in full, Fig. 1. The double oscillation in twenty-four hours, with the turning points about six hours apart, is well brought out. The average range between maximum and minimum is about 67″, two to four times larger than usually found by combining the results for several years.

Next, the declination ordinates as scaled for the solar hours were

[1] The diagrams were on exhibition at the recent meeting of the International Meteorological Conference held at Southport, England.

The Abstract is published with the permission of the Superintendent of the Coast and Geodetic Survey. The complete publication is deferred until the investigation has been extended over several lunations.

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tabulated according to lunar hours, by merely taking the hourly solar ordinate nearest to the particular lunar hour, or in case the lunar hour fell nearly midway between two solar hours, the mean of the two solar ordinates was taken. This was done for the entire lunation and the residuals again formed as before, with the results as exhibited in the broken curve of Fig. 1. There is practically no difference between this curve and the previous one. Hence, if magnetograph observations

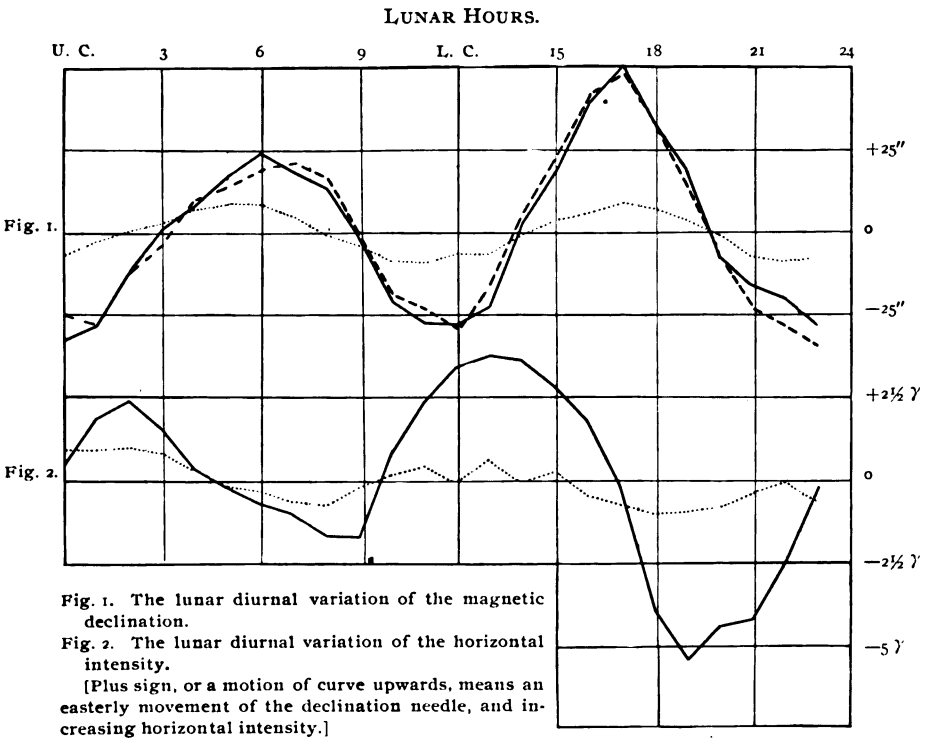

Fig. 1. The lunar diurnal variation of the magnetic declination.

Fig. 2. The lunar diurnal variation of the horizontal intensity.

[Plus sign, or a motion of curve upwards, means an easterly movement of the declination needle, and increasing horizontal intensity.]

possess the desired degree of accuracy, and disturbances are eliminated, the lunar diurnal variation can be obtained expeditiously and with sufficient accuracy from the usually published solar ordinates for each lunation separately, and thus an annual inequality of this interesting variation can be successfully investigated.

The dotted curve Fig. 1 exhibits the mean lunar diurnal variation of the declination as obtained at the Los Angeles[1] Magnetic Observatory during the three years October, 1882–October, 1883; October, 1885–Octo-

[1] Los Angeles, California. This observatory was operated by the U. S. Coast and Geodetic Survey, between 1882 and 1889, the magnetograph being of the old Adie pattern.

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ber, 1886, and October, 1888–1889; the period includes a year of maximum sun spot activity and a year of minimum sun spot activity.

The lunar diurnal variation in the horizontal intensity, as shown by the full curve, Fig. 2, was obtained from the solar hourly ordinates for the complete lunation in same manner as the second declination curve. No corrections for temperature changes were required, as on account of the means employed at this observatory, the temperature was so uniform as to make the corrections negligble. The double oscillation is again most satisfactorily shown. The average range between maximum and minimum is about 6.6 gammas (0.000066 C. G. S. unit.)

The mean result of the same three years of observations at Los Angeles, as for the declination, obtained with less refined instruments, is shown by the dotted curve, Fig. 2.

The vector diagram combining the changes in declination and horizontal intensity for the single lunation was also drawn and found to consist of a curve of two loops of unequal area.

In view of the success achieved within a limited period, there ought to be no reason now for observatories not publishing lunar diurnal variation results as well as those of the solar diurnal variation.

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SECOND INTERNATIONAL SEISMOLOGICAL CONFERENCE AT STRASSBURG.

HARRY FIELDING REID.[1]

In response to a call from the German Government, delegates were appointed by various countries to meet in Strassburg, from July 24th to 28th of the present year, to discuss the organization of an International Seismological Association. Official delegates were present from the following nineteen countries, namely: Germany, Argentine Republic, Austria, Belgium, Bulgaria, Chili, Congo, United States, Great Britain, Hungary, Japan, Italy, Mexico, Holland, Portugal, Roumania, Russia, Sweden, and Switzerland. France and Spain also had representatives, but they did not come as official delegates.

The meetings took place in the main assembly-room of the "Landesausschussgebäude," and were opened by the Prince of Hohenlohe-Langenburg, Imperial Governor of Alsace-Lorraine. He made an address of welcome to the delegates, and was followed by Professor Dr. Gerland, the director of the Imperial Central Seismological Station at Strassburg, who also welcomed the delegates and stated the object of the meeting.

The meetings for the discussion of the organization of the Association and of scientific questions, took place morning and afternoon. German, French, English, and Italian, were all used in the discussion, but the motions were translated into both French and German before they were voted.

The delegates, although officially sent by their respective governments, came as a rule, without special authority, and only acted an advisory part. The result of the deliberations was to decide upon a form of organization for an International Seismological Association. This will be submitted to all civilized nations by the State department of the German Government, and they will be invited to join the Association.

The important parts of the constitution are as follows:

The object of the Association is the study of seismological problems, whose solution is only possible by the co-operation of many observatories in all parts of the world. The principal means of attaining this object are:

a. Observations according to common principles;

b. Experiments on problems of special importance;

c. Foundation and support of seismological observatories in countries which need the pecuniary aid of the Association;

[1] Professor Reid was the official delegate from the United States.—ED.

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d. Organization of a Central Bureau for the collection, study, editing, and publication of the reports sent from various countries.

The members of the Association shall be the nations which may join. They are to make the following annual contributions through the department of State at Berlin:

a. Nations with a population of less than five million, $100.

b. Nations with a population between five and ten million, $200.

c. Nations with a population between ten and twenty millions, $400.

d. Nations with a population of more than twenty million, $800.

The organs of the Association are:

a. The General Assemby;

b. The Permanent Commission, and

c. The Central Bureau.

The General Assembly shall consist of delegates from the Nations which are members of the Association, and is to meet at least once in four years. Delegates from scientific societies and other persons, may be invited to attend the General Assembly.

The Permanent Commission shall consist of the Director of the Central Bureau and one delegate from each Nation.

It shall elect from its own number its President, Vice-President, and Secretary-General.

The Permanent Commission shall have general control of the affairs of the Association, and shall see that the resolutions of the General Assembly are carried out. It shall also direct the method of expenditure of the funds of the Association, which are to be used for:

a. Expenses of publication and administration;

b. Salary of the Secretary-General;

c. To subsidize theoretical work or experiments of exceptional importance which may have been ordered by the General Assembly.

d. For the foundation and support of seismological observatories founded by the Association, the observations of which are of general interest for the study of seismical phenomena.

A financial account shall be published in the proceedings of the Permanent Commission.

The Central Bureau shall be located at the Imperial Central Seismological Station at Strassburg, and the director of the latter shall be the director of the Central Bureau; the Central Bureau shall have the benefit of the assistants and resources of the Central Station.

The Central Bureau shall collect the reports from the different countries, edit and publish them. The director of the Central Bureau shall present an annual report covering the whole work of the Bureau, and shall also outline the work proposed for the following year.

The secretary-general shall make a report to every General Assembly on the work and condition of the Association. He shall attend to the

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publication of the proceedings of the Permanent Commission, of the deliberations of the General Assembly, and of investigations undertaken by order of the Association. He shall have charge of the general affairs of the Association under the direction of the President of the Permanent Commission.

The Association shall be formed for a period of twelve years, beginning April 1, 1904. Nations which join the Association may withdraw at the end of each period of four years, on giving six months' notice of their intention.

The various articles of this constitution were carefully debated, and, indeed, this took up the larger part of the time of the convention. It is not intended for the present, at least, to outline the "common principles" according to which observations should be made, but each Nation and observer is to be allowed the largest liberty in this respect. It was, however, unanimously decided that in the reports of earthquakes, Greenwich mean civil time should be used. A new scale of intensities for earthquakes was proposed, but it was decided that it was not advisable for the Association to adopt for the present any definite scale.

Some delegates wished the Association to give advice with respect to the best instruments to be adopted by observatories taking up this work, but it was decided that the Association was not prepared to give this advice, and that each observatory should select for itself the instruments which seemed best adapted to its purpose. A committee, however, was appointed to draw up an account of the various instruments now in use.

A number of scientific papers were read on various subjects connected with seismology, but in general, there was not sufficient time for a full discussion of their contents.

Under the direction of Professor Gerland and his able assistants, a visit was made to the Central Seismological Station, at Strassburg, to see the various instruments which are there recording, and to see the general arrangements of the building. An instrument which attracted much attention, was a newly made inverted pendulum of Professor Wiechert, of Göttingen, having a weight of 2000 kilograms and recording on smoked paper. The recording point magnifies the movement of the pendulum two hundred times.

The delegates were entertained most hospitably in Strassburg. The Prince of Hohenlohe-Langenburg gave a dinner in their honor, as did also the mayor of the city: and a very interesting excursion to the Vosges Mountains was made on Sunday, July 26th; a subscription dinner completed the social functions. The delegates were greatly pleased with their visit to Straussburg, and appreciated highly the courtesy shown them by all who took part in the arrangements for the meetings.

Johns Hopkins University, Baltimore, Maryland.

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STEPHEN JOSEPH PERRY, S. J., F. R. S.

Stephen Joseph Perry was born at London, August 26, 1833, of Catholic parents. His education covered a period of over nineteen years, about eight of which were passed at school at Gifford Hall, and at the Benedictine College at Douay; five more were spent at Rome, St. Acheul, and Stonyhurst, and two under De Morgan in London and Bertrand, Lionville, Delaunay, Cauchy, and Serret in Paris. Having entered the Society of Jesus in 1853, he studied theology the remaining four years as a preparation for the priesthood.

In 1860, he was called to Stonyhurst College as Professor of Physics and Mathematics, and to take charge of the Observatory, which, founded in 1838, primarily as a meteorological station, had begun under his predecessor, Father Weld, to establish a reputation for itself in meteorology and terrestrial magnetism. In that same year, 1860, was issued the first annual report in the form of a neat volume, in which were tabulated the mean results of the readings of the thermometers, barometers, rain-gauge and wind-gauge. He remained at Stonyhurst two years, leaving to enter St. Beuno's College, where he prepared himself in theology, as before mentioned.

In 1866, he entered the priesthood, after three years' probation in which, he resumed his original duties at Stonyhurst, where, with the exception of journeys undertaken in the interests of science, he remained until the last expedition, which proved fatal to him. He died at sea off the coast of French Guiana, December 27, 1889, and was buried at Demarara.

While Director of Stonyhurst Observatory, Father Perry greatly extended the work in the three branches of science taken up there—meteorology, terrestrial magnetism, and astronomy. To speak especially of terrestrial magnetism, besides the regular routine work of a magnetic observatory, special attention was paid to magnetic storms, auroræ and earthquakes, and several magnetic surveys were undertaken. These were surveys, in conjunction with Father W. Sidgreaves, of the west of France and of the east of France, and one of Belgium, in which he was assisted by Mr. W. Carlisle. In the course of some of his scientific voyages, Father Perry also determined the magnetic elements at the Cape of Good Hope, Kerguelen, Bombay, Aden, Port Said, Malta, Palermo, Rome, Naples, Florence, and Moncalieri, and at Nos Vey, Madagascar. These scientific voyages comprised, two to observe the Transit of Venus, and four to make observations of total solar eclipses. The last one he took part in was to the Salut Isles, off the coast of French Guiana, to observe

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the solar eclipse of 1889. He contracted in that unhealthy climate the fever which resulted in his death.

Besides being an able director, Father Perry was a gifted lecturer. Among his most important lectures were those delivered before the Royal Institution on the Transit of Venus and the Solar Surface; those before the Société Scientifique of Brussels, and the Catholic Scientific Congress at Paris; and at Montreal, in connection with the meeting of the British Association.

He was elected Fellow of the Royal Society in 1874, and was also a Fellow of the Royal Astronomical Society, and of the Royal Meteorological Society. Of societies outside of Great Britian, he was an Associate of the Pope's Academy of the Nuovo Lincei, the oldest established scientific society in Europe, as also of the Société Scientifique of Brussels, and the Société Geographique of Antwerp. In 1866, he received the honorary degree of D. Sc. from the University of Ireland. He served on several important scientific committees.

Besides the valuable reports of the Stonyhurst Observatory, he was the author of numerous articles in "Nature," and many papers by him are found also in the Proceedings of the Royal Society, and of the Royal Astronomical Society, and elsewhere.

Father Perry's aim, in all his scientific work was, to use his own words, "not to undertake any work that would be a mere repetition of what was being done better elsewhere."[1]

[1] The portrait of Father Perry was furnished by Father Sidgreaves, whereas the the biographical sketch is taken largely from Father Cortie's "Life of Perry," a copy of which was supplied to the Editor by Father Hagen.

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OBSERVATORIO MAGNETICO Y METEOROLOGICO DE LA ISLA DE "AÑO NUEVO."

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Terrestrial Magnetism
and
Atmospheric Electricity

VOLUME VIII DECEMBER, 1903 NUMBER 4

THE DIURNAL FIELD OF MAGNETIC DISTURBANCE.[1]

By Dr. W. van Bemmelen.

It has been known for some time that the Earth's magnetic force on days of disturbance shows a characteristic change, both in amount and direction, from the normal value as derived from quiet days. In 1895[2] the author inquired into this phenomenon by the method briefly described below.

Let h_s, d_s, v_s; h_1, d_1, v_1; h_2, d_2, v_2; h_3, d_3, v_3, etc., represent, respectively, the daily means of horizontal intensity, declination, and vertical intensity, on a day of disturbance and subsequent quiet days. For a number of n cases were computed the mean values:

$$H_s = \frac{h_{1.s} + h_{2.s} + \cdots h_{n.s}}{n}, \quad D_s = \frac{d_{1.s} + d_{2.s} + \cdots d_{n.s}}{n},$$

$$V_s = \frac{v_{1.s} + v_{2.s} + \cdots v_{n.s}}{n};$$

$$H_1 = \frac{h_{1.1} + h_{2.1} + \cdots h_{n.1}}{n}, \quad D_1 = \frac{d_{1.1} + d_{2.1} + \cdots d_{n.1}}{n},$$

$$V_1 = \frac{v_{1.1} + v_{2.1} + \cdots v_{n.1}}{n};$$

$H_2 =$ etc.

The values $(H_s - H_m)$ and $H(D_s - D_m)$, H being the mean value of the horizontal intensity, determine, with sufficient accuracy for the purpose, the horizontal component of the average dif

[1] Presented to the Royal Academy of Sciences at Amsterdam, October, 1903.
[2] *Meteorol. Zeitschr.* 1895, p. 321.

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ferential vector for the days of disturbance and the m following days. The angle α determined by $\tan \alpha = \frac{H(D_s - D_m)}{H_s - H_m}$ is the magnetic azimuth of the differential vector, which we may call the disturbing vector.

A first result of these calculations was found to be that this angle α is fairly constant for any one station; a second result, derived from a consideration of this azimuth for twenty-eight stations distributed over the Earth, was that, generally speaking, this disturbing vector is directed perpendicularly to the isochasms (lines of equal frequency of aurora polaris), pointing away from the pole of the aurora borealis.

As we can always suppose that the magnetic force is caused by an electric current directed perpendicularly to the vector, this result led to the hypothesis of a system of electric currents circulating around the Earth parallel to the isochasms, the strength of the current being increased during disturbance, and decreased at a greater or lesser rate afterwards.

As Schmidt[1] has made it plausible that the more quickly occurring disturbances are caused by wandering current vortices, we are led to the following supposition: A system of electric currents encompasses the Earth; at the occurrence of a magnetic disturbance, not only the strength of current is increased, but numerous current vortices are formed which wander over the Earth.

This system exhibits a strong analogy to the great cyclonic movement of the atmosphere around the poles, with its accompanying wandering depressions, as has been recently described by Hildebrand Hildebrandson.[2]

It being obvious to suppose that such a system of currents, with an axis not coinciding with the axis of rotation, but inclined at an angle of about 10°, must be influenced in some manner by the terrestrial rotation, the investigation was extended as follows:

Representing the hourly values of the horizontal intensity and declination on the first or second day following a day of disturbance by $h_1', h_2', h_3', \ldots h_{24}'$; $d_1', d_2', d_3', \ldots d_{24}'$, and on the second or third day or on a still later day by

$$h_1'', h_2'', h_3'', \ldots h_{24}''; \quad d_1'', d_2'', d_3'', \ldots d_{24}'',$$

[1] *Meteorol. Zeitschr.* 1899, p. 385.

[2] *Les bases de la meteorologie dynamique* No. 6, 1903.

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then for a number of cases were computed,

$$(h_1'' - h_1'),\ (h_2'' - h_2') \text{ - - - - } (d_1'' - d_1') \text{ - - - - } (d_{24}'' - d_{24}'),$$

and the averages of these respective values,

$$H_1,\ H_2 \text{ - - - - - } H_{24},\ D_1,\ D_2 \text{ - - - - - } D_{24}.$$

Letting the averages of these quantities be (H) and (D) respectively, then by taking the differences

$$\begin{aligned} \triangle\ h_1 &= H_1 - (H), & \triangle\ d_1 &= D_1 - (D), \\ \triangle\ h_2 &= H_2 - (H), & \triangle\ d_2 &= D_2 - (D), \\ &\text{etc.} & &\text{etc.} \\ \triangle\ h_{24} &= H_{24} - (H), & \triangle\ d_{24} &= D_{24} - (D), \end{aligned}$$

a system of hourly values was found for the components of the vector, representing the daily inequality of the vector of disturbance.

Vector diagrams were drawn according to these values, computed for a certain number of stations, but though they pointed to a real influence of terrestrial rotation, they were mostly too irregular to allow any conclusions to be reached as to the nature of this influence.

In 1899, Dr. Lüdeling[1] constructed the vector diagrams of the diurnal variation for the international polar stations and for Pawlowsk. He gives in his paper the rectangular components (NS and EW) for the horizontal vector. He found that the direction in which the vector curve progresses—whether *clockwise*, as prescribed by the Schuster and von Bezold researches, or *anti-clockwise*—depends primarily upon whether all days (disturbed and undisturbed), or simply the magnetically calm days (Wild's "normal" days), are embraced in the discussion.

The vector curves of the diurnal disturbing forces, with the exception of the one for Kingua Fjord (and partially for Godthaab), progressed in the *anti-clockwise* direction. He suggests, in conclusion, that the disturbances, as well as the diurnal variation, may be ascribed to a system of forces rotating around the Earth once in twenty-four hours, and that we may possibly be dealing with a system of ascending and descending electric currents rotating about some pole, as *e. g.* the magnetic or the polar-light pole.

[1] See *T. M.*, IV, p. 245.

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The present paper gives the results of the investigation of the daily field of disturbing force and its rotation referred to above.

The history of magnetic science has shown that wrong notions of magnetic phenomena, such as the secular and the diurnal variations, disturbances, etc., prevailed as long as these phenomena were being investigated at one or at a small number of stations, and that a true understanding was reached only after an inquiry into the phenomenon in question was made at widely distributed points.

Accordingly, our first task was to derive the daily horizontal and vertical components of disturbing force for a number of stations distributed as widely as possible over the globe. The available material is scant, the necessary dates for "quiet" days failing for many stations. We may expect, however, that the publication of the recent international observations will materially enlarge the data.

The material used is as follows:

The values of the horizontal component derived by Lüdeling have been used without change; for the vertical component the following quiet days have been taken into account:

	1883	
Cape Thordsen:	June	4, 5, 10, 12, 15.
	July	3, 4, 12, 20, 21, 22, 23, 28.
	August	4, 9, 10, 16, 17, 20.
Kingua Fjord:	June	4, 5, 6, 10, 11, 12, 15.
	July	3, 4, 12, 20, 21, 22, 23, 28.
Novaja Semlja:	June	4, 5, 15, 29.
	July	21, 22, 23, 28, 29.
	August	4, 9, 16, 17, 26, 31.
Bossekop:	June	5, 11, 15.
	July	21, 28, 29.
Point Barrow:	June	4, 5, 10, 11, 12, 15.
	July	3, 4, 20, 21, 22, 23, 28.
Jan Mayen, *Sodankylä*, *Fort Rae:*	June, July	Results taken directly from the respective publications.
Pawlowsk:	June	4, 5, 10, 11, 12, 15.
	July	3, 4, 12, 20, 21, 22, 23, 28.

The variations of the vertical intensity read at *Ssagastyr*, with the aid of a unifilar magnetometer provided with soft-iron induc-

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tion bars, show such abnormal changes, that they evidently are less trustworthy, and, accordingly, they have not been used.

For *Greenwich* the hourly means of selected quiet days are published each year. Mean values for the components have been computed for the months of June and July of the ten years 1890–1899.

For *Tiflis* the days designated as normal or quiet for the three elements (*H*, *D*, and *Z*) at *Pawlowsk* have been used. The months of June and July for the years 1880–1884, 1886, 1887 have been selected for the horizontal component, and for the vertical component August was added.

For *Washington* the same quiet days as those for *Pawlowsk* for the months of June and July of the years 1889–1892, and also of 1894, have been chosen (taking into account the difference in time).

For *Batavia* the author had an opportunity to select the quiet days from the original magnetograms. The same dates have been adopted for *Zi-ka-wei*.

They are:

	June	July
1890	13, 14, 25	3, 16, 27, 28
1891	10, 11, 13	8, 9, 11, 13
1892	11, 12, 18	7, 8
1893	8, 17, 24	6, 8, 9, 31
1894	8, 27	27
1895	13, 14, 15, 20, 26	8, 10, 19, 25
1896	1, 2, 7, 11, 12, 13, 23, 24	.....
1897	9, 10	5, 13, 18

For *Cape Hoorn*[1] (June–July, 1883) the results for quiet days are given in the publication[2] for that station.

The results of the calculations for all these stations—viz., the components x_s, y_s, z_s, of daily inequality in disturbing force—have been collected in Table I.

[1] "*Hoorn*" is the true original spelling.

[2] *Mission Scientifique du Cap Horn*, 1882–1883, T. III.

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TABLE I.

Diurnal Variation of Components of Disturbing Force.

[Unity = 0.00001 C. G. S.]

Local Mean Time	Kingua Fjord			Godthaab			Cape Thordsen			Jan Mayen			Fort Rae			Point Barrow			Novaja Semlja			Ssagastyr		
	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s
1a	+23	−17	−13	− 3	− 8	. .	− 8	+13	−32	−34	+34	−40	+ 6	−21	−24	− 7	−23	− 6	−52	+11	−10	− 8	−16	. .
2	+22	−13	−24	+ 4	− 7	. .	− 9	+17	−32	−51	+40	−26	− 3	−23	−28	−10	− 9	. .	−58	+16	− 4	−33	−11	. .
3	+24	−11	−30	− 1	− 1	. .	− 5	+28	−24	−65	+56	−30	−22	−26	−59	0	− 9	+24	−61	+19	− 4	−49	+ 5	. .
4	+26	− 9	−17	− 6	+16	. .	−11	+44	−56	−43	+49	−26	−42	−28	−81	+16	− 8	. .	−37	+18	− 4	−54	+ 4	. .
5	+21	+ 7	−18	− 8	+26	. .	−17	+47	−49	−32	+49	−16	−42	−24	−68	− 5	− 8	+19	−24	+14	+ 3	−48	+16	. .
6	+28	+13	−27	−34	+51	. .	−13	+44	−30	−14	+37	−17	−52	−24	−67	−50	− 5	. .	−16	+ 9	+17	−35	+12	. .
7	+15	+23	−27	−32	+61	. .	+ 8	+26	−14	+ 2	+24	− 7	−80	−11	−71	−68	− 4	+37	− 7	+ 3	+ 9	−13	+12	. .
8	+16	+34	−19	−15	+43	. .	+32	+16	− 3	− 7	+24	− 5	−89	− 4	−28	−73	0	. .	+16	+ 1	+ 4	−21	+ 6	. .
9	+ 7	+40	−31	− 3	+36	. .	+36	+15	− 8	+ 8	+10	− 1	−66	+ 2	+14	−60	+ 8	+38	+24	+ 2	− 1	−17	+ 1	. .
10	+11	+53	− 5	+14	+31	. .	+59	+ 4	+ 5	+26	+ 8	− 1	−36	+10	+ 4	−19	+ 3	. .	+25	+ 3	− 5	−14	− 3	. .
11	+15	+61	+ 5	+37	+30	. .	+67	+17	+18	+47	− 2	+ 1	− 3	+13	+ 6	− 4	+ 6	+ 1	+20	+ 6	−11	− 4	+ 8	. .
Noon	+ 4	+61	+33	+81	+32	. .	+57	+ 1	+31	+51	− 6	+ 8	+12	+27	+ 1	+ 6	+ 4	. .	+10	− 1	−12	+ 5	+10	. .
1p	−28	+39	+57	+86	+11	. .	+34	0	+25	+72	−13	+17	+24	+37	− 5	+13	+12	− 8	+19	− 1	−15	+ 7	+ 7	. .
2	−56	+12	+36	+35	+ 5	. .	+12	− 9	+51	+60	−29	+31	+42	+40	−11	+10	+24	. .	+45	0	−20	+17	+ 9	. .
3	−56	− 4	+34	+10	− 3	. .	+ 4	−19	+38	+70	−47	+40	+58	+42	+ 1	+15	+21	−14	+40	− 5	−17	+30	+11	. .
4	−36	− 8	+21	−26	−21	. .	−14	−43	+59	+62	−46	+53	+56	+36	+43	+27	+17	. .	+31	−10	− 3	+41	+12	. .
5	−40	−22	+20	−30	−20	. .	−25	−36	+52	+ 7	−36	+56	+61	+28	+58	+33	+13	−38	+39	−10	− 1	+43	+10	. .
6	−29	−35	+16	−32	−36	. .	−47	−37	+39	+ 6	−44	+28	+55	+18	+65	+36	+11	. .	+53	−11	+ 6	+42	+10	. .
7	−12	−43	+ 6	−27	−51	. .	−35	−34	+25	−20	−42	+32	+38	− 2	+94	+42	+15	−42	+38	−13	+12	+56	+ 8	. .
8	− 5	−49	− 3	−18	−51	. .	−45	−33	+12	−42	−33	+15	+36	− 7	+75	+44	+ 5	. .	+20	−17	+13	+49	− 3	. .
9	+ 2	−45	−13	−13	−49	. .	−29	−24	+ 3	−50	−26	− 4	+28	−16	+51	+42	− 6	− 8	− 8	−18	+13	+26	−14	. .
10	+14	−35	− 1	−10	−42	. .	−25	−25	−20	−19	− 7	−23	+ 5	−26	+43	+26	−15	. .	−25	−15	+12	+19	−18	. .
11	+14	−28	−21	0	−32	. .	− 9	−12	−40	−21	+ 2	−36	+ 2	−29	+ 3	+ 1	−23	− 6	−49	− 6	+10	− 2	−23	. .
Midnight	+15	−20	−16	− 9	−12	. .	− 8	− 6	−54	−27	+11	−47	+ 0	−11	−13	− 6	−32	. .	−45	+ 9	− 2	−31	−34	. .

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TABLE I—Continued.

Diurnal Variation of Components of Disturbing Force.

[Unity = 0.0000.1 C. G. S.]

Local Mean Time	Bossekop			Sodankylä			Pawlowsk			Greenwich			Washington			Tiflis			Zi-wa-kei			Batavia			Cape Hoorn		
	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s
1a	−69	+25	+30	−59	+17	−41	− 3	+ 4	+15	. .	. .	. .	. .	. .	. .	. .	. .	. .	+0.4	+0.2	+0.8	−1.4	−0.5	−0.9	−0.4	−3.0	+0.4
2	−78	+24	+54	−52	+10	−37	+ 2	+ 3	+13	+0.7	+1.0	+8.2	+1.7	−2.2	+2.8	+4.7	+2.2	+1.6	+0.8	+1.1	+0.7	−0.6	+0.3	−1.0	−2.2	−2.7	+0.2
3	−92	+37	+65	−45	+11	−32	+ 1	− 1	+12	. .	. .	. .	.	.	.	. .	. .	. .	+1.3	+1.9	+0.7	0.0	+0.7	−1.2	−0.5	−3.7	−0.2
4	−62	+27	+74	−32	+ 7	−23	− 2	+ 1	+ 9	+0.8	+2.0	+3.7	+1.2	−1.5	+4.4	+4.2	+1.2	+2.0	+1.5	+2.0	+0.8	+0.8	+1.2	−1.1	−0.4	−3.3	−0.5
5	−38	+16	+51	−22	+ 2	−14	− 2	− 4	+ 4	. .	. .	. .	. .	. .	. .	. .	. .	. .	+1.0	+2 9	+0.7	+1.7	+1.2	−1.1	+0.8	−2.1	−0.4
6	−19	+ 3	+40	−13	− 2	− 1	− 2	− 4	+ 4	+0.9	+4.6	+6.9	+2.2	+0.4	+4.7	+3.2	−1.3	+2.4	+0.4	+2.3	+0.5	+2.8	+1.5	−1.6	+2.4	−1.0	−1.1
7	0	+ 3	+12	− 2	0	− 9	− 3	− 2	+ 2	. .	. .	. .	. .	. .	. .	. .	. .	. .	+0.9	+1.2	+1.2	+2.6	+1.6	−0.3	+1.1	+1.4	+0.3
8	+ 6	0	− 1	+ 1	− 1	−10	− 3	− 2	+ 1	−0.5	+5.3	+5.0	−1.5	+0.5	+3.0	+1.4	−4.1	+1.0	+0.5	+0.4	+1.4	+3.0	+0.7	+1.0	+2.2	+2.9	−0.4
9	+ 9	0	− 7	+ 1	+ 1	+15	− 5	0	+ 1	. .	. .	. .	. .	. .	. .	. .	. .	. .	+0.1	−0.4	+1.2	+3.4	−0.3	+1.2	+3.5	+3.4	−0.9
10	+17	+ 2	− 9	+ 5	+ 5	+18	− 5	− 1	0	−2.2	+2.2	+2.8	−1.5	+1.9	+2.2	+0.4	−0.6	+0.2	+0.3	−1.1	+1.2	+3.2	−1.3	+1.9	+2.4	+3.2	−0.3
11	+15	+ 1	−11	+ 5	+ 5	+24	− 7	0	− 4	. .	. .	. .	. .	. .	. .	. .	. .	. .	−1.2	−1.2	+1.0	+3.0	−1.4	+3.4	+1.6	+3.1	−0.3
Noon	+36	− 1	−38	+16	+ 3	+27	− 3	− 3	−10	−0.3	−3.8	−1.3	−1.0	+2.9	−1.0	−3.2	+1.5	−1.8	−1.4	−0.6	0.0	+2.0	−0.8	+2.4	+0.6	+1.9	−1.6
1p	+55	− 4	−57	+21	− 1	+26	− 2	− 2	−10	. .	. .	. .	. .	. .	. .	. .	. .	. .	−1.4	−1.2	+0.5	+1.5	−0.8	+1.7	−0.1	+1.9	−0.3
2	+60	−12	−57	+36	− 7	+21	+ 1	− 3	−13	−1.7	−5.6	−0.3	0.0	+1.6	−2.2	−4.1	+1.4	−0.8	−1.0	−1.4	+ 1.1	0.0	−0.1	−0.2	+0.6	+1.8	−1.1
3	+69	−20	−77	+42	−10	+18	+ 5	− 2	−13	. .	. .	. .	. .	. .	. .	. .	. .	. .	−0.3	−1.7	0.0	−1.9	+0.8	−0.1	+1.3	+1.6	−0.4
4	+75	−23	−75	+48	−15	+26	+ 8	− 3	−14	0.0	−3.5	−8.1	+1.6	−1.0	−3.9	−4.0	−1.4	−1.2	−1.1	−1.6	0.0	−2.2	+0.7	0.0	+1.1	+1.1	−0.7
5	+89	−31	−76	+60	−14	+24	+13	− 1	−12	. .	. .	. .	. .	. .	. .	. .	. .	. .	−0.4	−0.5	−0.7	−2.7	+1.0	−0.4	+0.4	+0.9	−0.2
6	+73	−29	−63	+47	−16	+10	+ 7	0	− 8	+1.3	−1.4	−11.6	−0.6	+0.2	−4.4	−1.6	−0.3	−0.9	−0.3	−0.0	−0.8	−3.2	+1.0	−0.3	−1.7	+1.5	+0.1
7	+48	−32	−28	+40	−16	+14	+ 7	+ 2	− 5	. .	. .	. .	. .	. .	. .	. .	. .	. .	−1.5	−0.6	−1.1	−2.5	+0.6	−0.1	−2.2	+0.1	+1.1
8	+27	−25	−12	+16	−11	+ 4	+ 3	+ 1	− 1	+1.6	−0.8	−8.4	−2.8	+0.6	−4.9	−0.9	+1.9	−1.0	−0.4	−0.4	−1.5	−2.4	+0.1	−0.2	−2.5	0.0	+1.5
9	−12	− 8	+19	− 9	− 1	− 6	+ 2	+ 4	+ 3	. .	. .	. .	. .	. .	. .	. .	. .	. .	+0.4	−0.3	−1.3	−2.9	−0.6	0.0	−1.5	−0.5	+1.3
10	−43	− 1	+53	−19	+ 1	−14	− 2	+ 4	+ 5	+1.1	−0.4	+1.4	−0.2	+0.8	−1.6	−0.5	+2.6	−0.9	+0.9	−0.5	−1.6	−3.4	−0.6	−0.1	−2.7	−0.5	+1.3
11	−62	+13	+53	−37	−10	−19	− 4	+ 5	+ 9	. .	. .	. .	. .	. .	. .	. .	. .	. .	+0.5	−0.7	−1.4	−2.4	−1.2	−0.4	−2.9	−2.8	+0.6
Midnight	−80	+26	+48	−48	+13	−19	− 5	+ 3	+12	+0.9	+0.4	+4.4	+0.4	−2.8	+1.5	+0.1	+4.0	−0.6	−0.6	+0.1	+0.7	−1.8	−0.8	−0.8	−2.1	−3.7	+1.2

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VECTOR DIAGRAMS OF THE HORIZONTAL COMPONENT OF THE DIURNAL DISTURBING FORCE.

The first plate[1] exhibits these vector diagrams for *Kingua Fjord*, *Godthaab*, *Jan Mayen*, *Sodankylä*, *Greenwich*, *Tiflis*, *Zi-ka-wei*, *Batavia*, and *Cape Hoorn*, drawn with the aid of "smoothed" components, and using different scales, in order to preserve the general shape as much as possible.

The characteristic features of these diagrams, taking them in the order of succession determined by these characteristics, briefly described are:

Kingua Fjord. The vector moves clockwise throughout the day, with only small change in magnitude.

Godthaab. From 3^ha till 3^hp the vector moves anti-clockwise, and clockwise during the rest of the day; it vanishes as the direction of rotation changes. The vector diagram approaches the form of the figure 8.

Cape Thordsen. The diagram for this station may be considered to be derived from that of the preceding station of *Godthaab* by turning around the afternoon part in which the vector rotates clockwise. At 1^ha and 4^hp the vector nearly vanishes, but the rotation is anti-clockwise for the whole day.

Jan Mayen, *Fort Rae*, *Point Barrow*, *Novaja Semlja*, and *Ssagastyr.* The vector moves more or less regularly in an anti-clockwise direction; at the hours after midnight and noon it is larger than at about midnight and noon.

This latter feature is strongly developed at *Bossekop;* hence the diagram for this station exhibits a very oblongated form.

At *Sodankylä* the lower parts of the diagram seem to have crossed each other, forming a small loop. The curve progresses partly in the clockwise direction and partly in the opposite direction.

Pawlowsk. The vector moves anti-clockwise in the morning and clockwise in the afternoon; the diagram does not show the figure-8 form, but is partially curved inwardly, and approaches the simpler form of the *Greenwich* diagram, where the vector rotates regularly for almost the whole day in a clockwise direction.

Tiflis. The direction is anti-clockwise for the first part of the day and clockwise during the second part, the diagram showing the

[1] Both plates were printed at Batavia, and the requisite number furnished to the Journal by the author.—ED.

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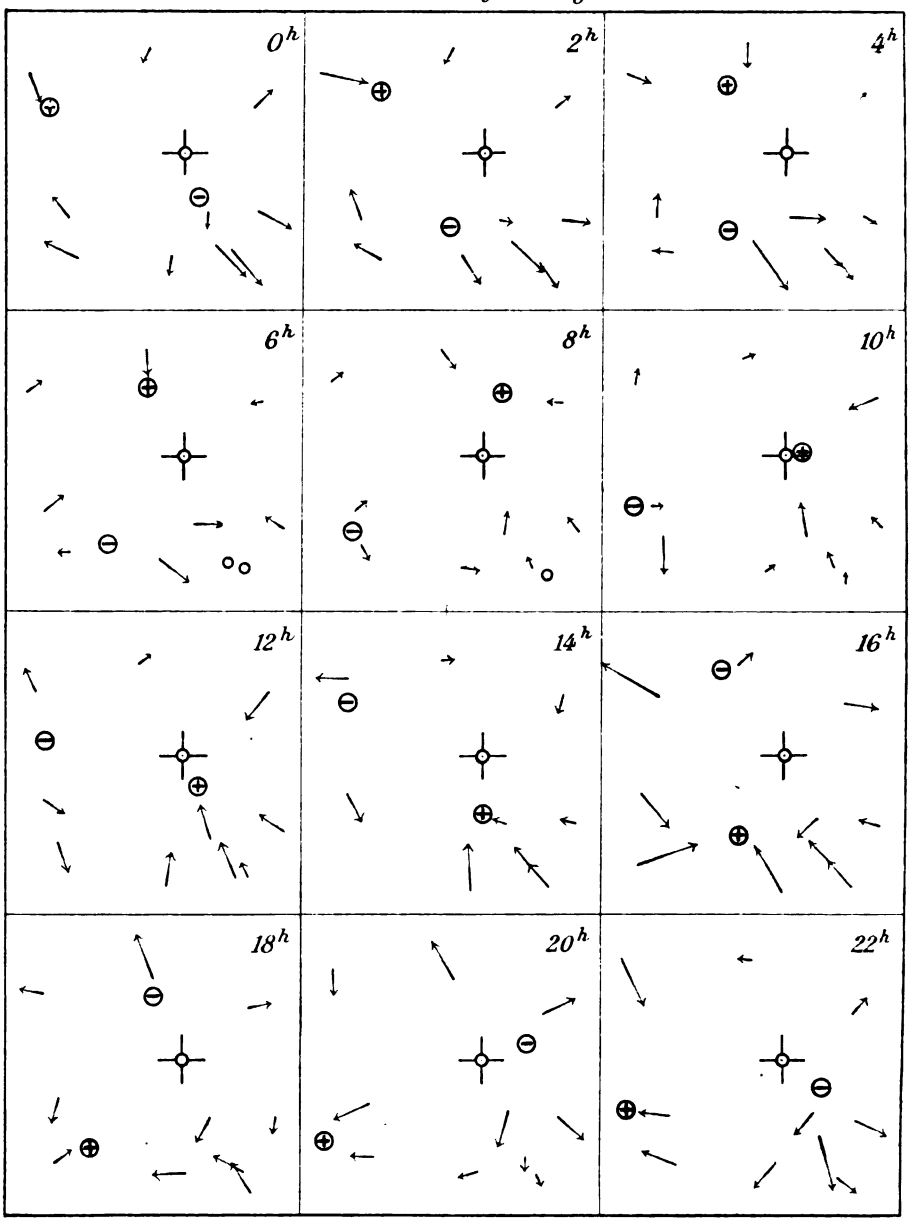
Disturbing Vectors in the Arctic Region.

Mean civil time of Göttingen.



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Daily Variation of Disturbing Force.

Vectordiagrams of horizontal component

Curves of vertical component.

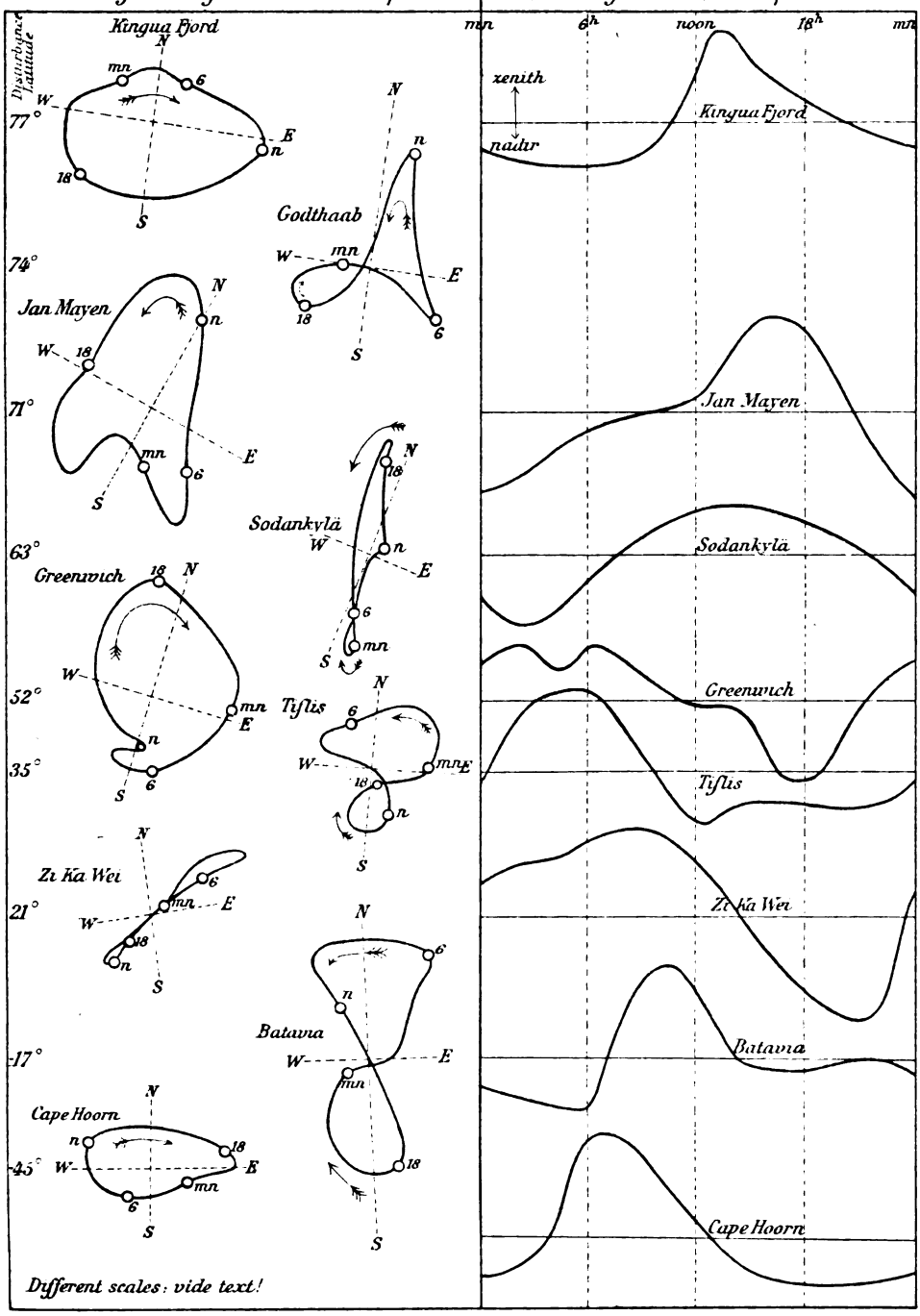

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figure-8 form and the vector vanishing before midnight and before noon.

Also for *Washington* such a diagram has been found, but of a more complicated character, evidently an effect of insufficient material. Notwithstanding, the vector rotates anti-clockwise regularly from 4^h a till 4^h p.

Zi-ka-wei. The diagram may be compared with that of *Sodankylä*. For both stations the diagram is so oblongated that the vector may be said to keep a constant direction, changing only in amount. The direction is nearly N/S for *Sodankylä*, but more E/W for *Zi-ka-wei*.

Batavia. The diagram is almost the same as that for *Tiflis*, only that the vector vanishes in this case shortly *after* midnight and noon.

The diagram of our most southerly station, *Cape Hoorn*, shows nearly the same features as that for *Greenwich*.

These stations for which diagrams have been described are recapitulated here, together with their geographical and their auroral latitudes. By the latter are meant the complements of the spherical distance from the pole of the aurora borealis.

Station	Latitude Geogr.	Auroral.	Station	Latitude Geogr.	Auroral.
Kingua Fjord	67°	77°	Sodankylä	68°	63°
Godthaab	64	74	Pawlowsk	60	54
Cape Thordsen	78	73	Greenwich	51	52
Jan Mayen	71	71	Washington	39	51
Fort Rae	63	70	Tiflis	42	35
Point Barrow	71	70	Zi-ka-wei	31	21
Novaja Semlja	72	63	Batavia	— 6	—17
Ssagastyr	73	62	Cape Hoorn	—55	—45
Bossekop	70	66			

The regularity in decrease shown by the auroral latitude, as contrasted with the irregular succession of geographical latitudes, is obvious; this is not wholly unexpected, as the vector of disturbance is directed perpendicularly to the isochasms, which have a course resembling that of true parallels around the auroral axis. And as these isochasms show certain deviations from the true auroral parallels, the small irregularity in the succession above mentioned shown by *Bossekop* and *Sodankylä* (respectively 66° and 63°) may be safely disregarded.

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The deviations of the isochasms from the auroral parallels make it impossible to determine accurately the place of the aurora-pole. From his observations of aurora, Nordensköld[1] adopted 81° N and 80 W, this place corresponding very nearly with the point where the meridians of disturbing vectors, mentioned above, converge. (Nachstörungsmeridiane, Cf. *Meterol. Zeitschr.* 1895 l. c.)

It is by reason of this uncertainty in the place of aurora-pole, that for our purpose another pole has been used, situated close to it, viz., in 79° N and 78° W, which may be called the pole of disturbance, and which will be considered further on.

VERTICAL COMPONENT OF THE DIURNAL DISTURBING FORCE.

(Directed positive towards zenith.)

In general this component exhibits a single diurnal variation with amplitude of the same order as for the horizontal component. For the stations: *Kingua Fjord*, *Cape Thordsen*, *Jan Mayen*, *Fort Rae* and *Sodankylä* the character of the inequality is chiefly the same with a minimum in the morning and a maximum in the afternoon. For *Novaja Semlja* we find two maxima and two minima and a small amplitude; the oscillation seems to be of a transitional form between the former type and that for *Pawlowsk*, *Greenwich*, *Tiflis* and *Zi-ka-wei*, where we find just the contrary type with a maximum in the morning and a minimum in the afternoon.

In two cases this regular system is broken, viz. for *Point Barrow* and *Bossekop* where the diurnal inequality is just the contrary of what is to be expected. This is especially remarkable for *Bossekop*, as the corresponding horizontal hourly vectors at the neighboring station, *Sodankylä*, have nearly the same directions as those at *Bossekop*.

The rest of the stations falling in so well with the general system of the diurnal inequality of the vertical component, I think it best to consider these two cases as local deviations caused perhaps by abnormal phenomena of induction discussed later.

The inequality at *Batavia* shows a maximum at about noon and a minimum in the morning, and for *Cape Hoorn* we find the same type again as for *Pawlowsk*, *Greenwich*, *Tiflis*, and *Zi-ka-wei*.

A tabulation of the direction of the horizontal vector and of the maxima and minima of the vertical component is as follows:

[1] *Ann. de Chimie et de Physique*, 1884.

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Latitude of Disturbance	Station	Horizontal vector moves	Vertical component has a maximum in the	minimum in the
77°	Kingua Fjord	clockwise	afternoon	morning.
74	Godthaab	clockwise and anticlockwise	?	
73	Cape Thordsen	anti-clockwise	afternoon	morning.
71	Jan Mayen	"	"	"
70	Fort Rae	"	"	"
70	Point Barrow	"	morning!	afternoon!
63	Novaja Semlja	"	tends to disappear.	
62	Ssagastyr	"	?	
66	Bossekop	"	morning!	afternoon!
63	Sodankylä	anti-clockwise and clockwise	afternoon	morning.
54	Pawlowsk	clockwise and anti-clockwise	morning	afternoon.
52	Greenwich	clockwise	"	"
51	Washington	anti-clockwise and clockwise	"	"
35	Tiflis	" " "	"	"
21	Zi-ka-wei	constant direction	"	"
—27	Batavia	anti-clockwise and clockwise	noon	morning.
—45	Cape Hoorn	clockwise	morning	afternoon.

Having thus investigated and correlated the character of the vector diagrams and the inequality of the horizontal and the vertical components at various stations, the natural step next was to study the synchronous system of vectors for different moments during one rotation of the Earth.

For this purpose we may restrict ourselves to the Arctic stations which lie relatively close to each other; the original observations at these stations having been taken at the Göttingen hours they are consequently truly synchronous.

To obtain a survey of these synchronous systems, 12 maps of the north polar cap have been constructed in stereographic projection. They are reproduced on the first plate (left hand side), inserted between pages 160 and 161.

The star with four rays represents the north pole, and the arrows give the direction and length of the horizontal vectors. The values of the components x_s and y_s, as given by Lüdeling in his quoted paper, have been used.

The names of the stations, viz. Kingua Fjord, Godthaab, Cape Thordsen, Jan Mayen, Bossekop, Sodankylä, Novaja Semlja, Ssagastyr, Point Barrow, and Fort Rae have not been inscribed in order not to confuse the aspect of the system of synchronous vectors corresponding to the 12 moments: 0^h, 2^h, 4^h - - - - 22^h mean time of Göttingen. An inspection of these 12 maps shows

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that one portion of the vectors points towards one focus, and that the other portion radiates from another focus.

This is especially striking for the vectors at the neighboring stations, Cape Thordsen, Jan Mayen, Bossekop, Sodankylä and Novaja Semlja for the hours, 0^h, 12^h, 14^h, 22^h.

On each map the places of these foci have been indicated by small circles in which a + or — sign has been inscribed, the + sign for the focus towards which the vectors point, and the — sign for the one from which they radiate. As there is chance for personal bias in the choice of these places, the maps are reproduced subject to the reader's criticism.

For a determination of the foci a rectangular system of co-ordinates, with the origin in the north pole, has been used. For the positive X axis and positive Y axis, respectively, the meridians of 180° and 90° W from Greenwich have been taken. For unit of length 2 tan 0°.5 has been chosen, because the maps have been drawn in stereographic projection from the south pole; accordingly $\sqrt{(x^2+y^2)} = \tan p$, p being the polar distance expressed in degrees. As p is small for most Arctic stations, we may take p for tan p, and consequently consider one degree as the unit of length.

Göttingen mean time	Positive focus x	Positive focus y	Negative focus x	Negative focus y
Midnight	7.4	—22.2	— 8.2	1.6
2^h	9.6	—17.0	—13.2	— 5.4
4	11.2	—11.0	—13.2	— 8.8
6	11.2	— 6.2	—16.0	—11.6
8	8.8	2.2	—12.6	—21.2
10	0.0	2.2	— 8.8	—28.0
Noon	— 4.4	2.2	2.2	—23.6
14	— 8.8	— 0.6	8.8	—23.6
16	—11.8	— 6.6	13.8	—10.4
18	—14.0	—15.4	9.4	— 6.0
20	—13.2	—26.2	2.8	8.2
22	— 8.8	—30.2	— 6.2	6.2
Mean	— 1.1	—10.7	— 3.4	—10.2

The 12 maps show that both foci change their positions from hour to hour; combining the 12 positions for each focus in a special map, it is obvious that the orbit for each approaches a common circle, in which the foci lie diametrically opposite to each other.

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To investigate this, the harmonic formulæ representing the four series, respectively for x_+, x_-, y_+, and y_-, have been computed.

$$+ \text{ focus } \begin{cases} x_+ = -- \ 1.1 + 13.5 \sin (t + 15°) + 2.1 \sin 2 (t + 19°) \\ y_+ = - \ 10.7 + 14.3 \sin (t + 14° - 90°) + 2.4 \sin 2(t - 2°) \end{cases}$$

$$- \text{ focus } \begin{cases} x_- = - \ 3.3 + 13.6 \sin (t + 24° + 180°) + 3.2 \sin 2(t - 15°) \\ y_- = - \ 10.2 + 15.7 \sin (t + 24° + 90) + 3.0 \sin 2(t - 50°) \end{cases}$$

The mean values of x_+, y_+, x_-, and y_-, viz., the constant terms of these formulæ, are nearly the same for both foci:

$$-1.1 \text{ and } -3.4 \quad ; \quad -10.7 \text{ and } -10.2.$$

Accordingly both paths have nearly the same central point.

The terms of the second order are small compared with those of the first order; neglecting them and considering those of the first order only, we see that the amplitudes are nearly of the same magnitude, and that the phase angles, viz. for x - - - - 15° and 24° + 180° and for y - - - - 14°—90° and 24° + 90°, differ nearly 180°, thus pointing to a circular path, in which the two foci have a diametrical position.

If we adopt the path as being the same for both foci, having its center at $x_0 = \frac{1}{2}(-1.1 - 3.4) = -2.3$, and $y_0 = \frac{1}{2}(-10.7 - 10.2) = -10.5$ and the foci occupying diametrical positions, the values: $(x - x_0)_n^h$, $(y - y_0)_{(n+6)^h}$, $-(x - x_0)_{(n+18)^h}$, $-(y - y_0)_{(n+18)^h}$ must represent the same quantity, and we may derive a new set of 12 values by taking the mean of each group of four. The harmonic formula computed for this set is:

$X_+ = -2.3 + 14.5 \sin (t + 22°) + 1.3 \sin 2(t + 28°)$.

The term of the second order has been still more diminished; furthermore the phase angles, viz. the angles $2 \times 19°$, $-2 \times 2°$, $-2 \times 15°$ and $-2 \times 50°$, show no regularity at all; accordingly we are justified in neglecting the term of the second order and in putting forth the conclusion:

The positive and negative foci of the Arctic vectors of the diurnal variation of the disturbing force move daily in a clockwise direction, with constant velocity and diametrically opposite to each other in a circular path of 14°.5 radius, having its center in 79° N and 78° W.

Combining the two results, viz.:

1°. The Arctic vectors point to a couple of foci, which rotate daily clockwise around the pole of disturbance;

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2°. The character of the vector diagrams is chiefly dependent on the distance from this same pole; it is quite natural to draw the conclusion:

The daily inequality of disturbing force is caused by a constant field of force rotating from E to W around the axis of disturbance.

This constancy should be understood in this way, that the rotating field suffers only minor alterations, when the disturbance influence to which the Earth is exposed does not vary.

For the pole of aurora borealis, I accepted 80°.5 N and 80° W and according to Schmidt, the magnetic axis for 1885 cuts the Earth's surface in 78°.5 N and 68°.5 W, hence in the vicinity of the place where the disturbance axis found above, cuts the surface.

THE DIURNAL FIELD OF DISTURBANCE.

In order to obtain a representation of this field it is best to distribute the successive hourly values of the components of a certain number of stations, situated on different parallels along the parallels and to draw the lines of equal vertical component together with the horizontal vectors. Parallels must be taken with regard to the axis of disturbance.

It is obvious that the features of the system of lines of equal vertical component will suffer strongly from local deviations from the general type of inequality pertaining to the region in which the station is situated. For instance, if to the vertical components of the stations: Kingua Fjord, Cape Thordsen, Jan Mayen, and Sodankylä, which exhibit one and the same type of inequality, are added those for Barrow and Bossekop, of the contrary type, then the lines of equal vertical component will acquire a distorted aspect. The aim being a knowledge of the causes of the phenomenon, a representation of the field exhibiting only the chief characteristic features free from local deviations is required. The investigation of the local deviations is of later care; for the present the knowledge that important deviations exist may be considered to be sufficient.

Of course we may suppose the field to change during one rotation in such a degree, that it would be necessary to derive a representation of it for each hour, but the agreement between most of the vector diagrams (the two stations: Point Barrow and Bossekop included) points to the contrary conclusion.

Just as Schuster,[1] in his representation of the diurnal variation field, selected a small number of stations situated on parallels

[1] *Philosophical Transactions* 180, p. 467.

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already known as critical for the phenomenon, so in our case those stations have been selected, which have well developed diagrams, characteristic for each of the different types.

Accordingly Kingua Fjord, Jan Mayen, Sodankylä, Greenwich, Tiflis, Zi-ka-wei, Batavia, and Cape Hoorn have been chosen; (Godthaab has been omitted, the vertical component for that station not being available).

First, the hourly values of the components for these stations have been smoothed graphically, because it was clear that the irregularities in the series had been caused chiefly by want of material. From the smoothed curves representing the values of x_s, y_s, and z_s for the selected stations, the values for the full hours of Göttingen mean time have been read. They are given in Table II. Now these values have been computed in most cases for the same pair of months, viz., June—July, but not for the same years. As it is probable that the diurnal inequality of disturbing force increases and decreases together with the force itself in the eleven year period, the figures are not comparable directly. A factor reducing them to the same year may be found as follows:

In the "Observations made at the Royal Magnetical and Meteorological Observatory at Batavia," 1898 part II, table 69, we find the mean horizontal disturbance (s_h) per day and from these values we may derive the formula

$$s_h = 22 + 1.00\, R\ ,$$

R being Wolf's Sun-spot number.

With this formula we find for the reducing factors: Greenwich, 1.27; Tiflis, 1.27; Batavia, 1.17.

As these factors differ not much from unity and are moreover approximations, and also as the components of these stations themselves are small in comparison with Arctic values, no use has been made of these factors.

The construction of the field has been performed in the following manner.

A map of the Earth has been constructed after Mercator's projection, not with the axis of rotation as chief axis, but with regard to the axis of disturbance. The great circle passing through the pole of disturbance and the place, where the Sun stands in the zenith at Greenwich mean noon of July 1st, has been chosen as middle or zero meridian.

The place occupied in this projection by the other stations selected has been computed to be:

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TABLE II.

Diurnal Variation of Components of Disturbing Force.
Smoothed Values for Eight Selected Stations.

[Unity = 0.00001 C. G. S.]

Mean Goettingen Time	Kingua Fjord			Jan Mayen			Sodankylä			Greenwich			Tiflis			Zi-ka-wei			Batavia			Cape Hoorn		
	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s	x_s	y_s	z_s
1a	− 5	−49	+ 2	−27	+16	−47	−52	+13	−38	+0.8	+4.8	+5.0	+4.5	+1.6	+1.9	0.0	0.0	+1.2	+3.2	+0.9	+0.4	−1.4	−1.2	+1.4
2	+ 3	−45	− 3	−35	+30	−40	−44	+10	−37	+1.2	+4.7	+7.4	+4.1	+0.7	+2.1	−0.4	−0.5	+1.1	+3.4	0.0	+1.5	−1.4	−1.9	+1.4
3	+ 9	−36	− 8	−41	+34	−34	−33	+ 6	−31	+1.7	+5.0	+7.4	+3.6	−0.4	+2.3	−0.8	−0.8	+1.1	+3.3	−1.1	+2.3	−1.2	−2.4	+1.3
4	+14	−28	−12	−65	+52	−28	−22	+ 2	−23	+1.2	+5.4	+5.0	+2.9	−1.9	+2.1	−1.1	−1.0	+0.9	+2.9	−1.5	+2.8	−0.8	−3.1	+1.0
5	+18	−21	−16	−46	+53	−23	−12	0	−13	−0.6	+5.2	+3.6	+2.0	−3.7	+1.6	−1.2	−1.1	+0.7	+2.3	−1.1	+2.6	+0.1	−3.5	+0.8
6	+21	−17	−19	−30	+46	−18	− 2	− 1	− 3	−3.3	+3.6	+5.6	+1.2	−3.8	+1.1	−1.2	−1.2	+0.4	+1.4	−0.7	+1.5	+0.7	−3.7	+0.5
7	+23	−13	−21	−19	+37	−13	0	0	+ 5	−4.6	+1.7	+6.9	+0.7	−1.5	+0.4	−1.1	−1.3	+0.1	+0.3	−0.2	+0.4	+1.3	−3.7	+0.2
8	+24	− 9	−23	− 8	+29	− 9	+ 1	+ 2	+12	−4.8	0.0	+5.9	+0.2	−0.1	−0.3	−1.0	−1.2	−0.2	−1.2	+0.3	0.0	+1.7	−3.3	−0.2
9	+24	− 3	−24	+ 1	+21	− 4	+ 4	+ 5	+17	−4.9	−0.9	+4.7	−1.6	+1.0	−1.1	−0.9	−1.0	−0.5	−2.2	+0.7	−0.2	+2.0	−2.5	−0.4
10	+23	+ 5	−24	+11	+13	− 2	+ 8	+ 5	+21	−5.0	−1.3	+3.6	−3.5	+1.7	−1.5	−0.8	−0.8	−0.8	−2.6	+0.9	−0.2	+2.2	−1.2	−0.5
11	+22	+14	−24	+35	+ 6	− 1	+15	+ 3	+24	−4.8	−1.3	+2.0	−4.0	+1.8	−1.3	−0.7	−0.6	−1.1	−2.9	+1.0	−0.2	+1.9	+0.6	−0.5
Noon	+20	+23	−23	+43	− 1	+ 2	+23	− 1	+25	−4.3	−0.5	−0.1	−4.2	+1.0	−1.1	−0.6	−0.5	−1.3	−3.0	+0.8	−0.2	+1.4	+2.4	−0.5
1p	+18	+32	−21	+56	− 8	+ 8	+32	− 6	+26	−3.5	+0.3	−1.3	−4.2	−0.5	−1.0	−0.5	−0.4	−1.4	−3.1	+0.2	−0.1	+0.8	+4.0	−0.6
2	+15	+42	−16	+65	−17	+18	+41	−10	+26	−2.5	−0.7	−0.4	−3.7	−1.5	−1.0	−0.4	−0.4	−1.5	−3.1	−0.4	−0.1	+0.2	+4.6	−0.6
3	+11	+53	− 7	+70	−28	+30	+51	−14	+25	−1.3	−3.5	−1.0	−2.2	−1.0	−1.0	−0.2	−0.4	−1.4	−3.0	−0.7	−0.1	−0.1	+4.1	−0.6
4	+ 7	+61	+ 7	+68	−40	+41	+60	−15	+23	+0.6	−4.4	−6.0	−1.4	+0.1	−1.0	0.0	−0.1	−0.8	−2.4	−1.0	−0.3	−0.3	+3.3	−0.6
5	− 3	+61	+33	+58	−44	+53	+50	−16	+19	+2.7	−4.9	−9.3	−1.1	+1.1	−1.0	+0.2	+0.3	+0.4	−2.0	−0.9	−0.6	−0.5	+2.5	−0.6
6	−28	+39	+57	+29	−44	+56	+35	−15	+15	+6.3	−4.0	−11.0	−0.8	+1.9	−1.0	+0.7	+0.9	+0.8	−1.4	−0.5	−0.9	−0.6	+2.1	−0.6
7	−56	+17	+43	− 1	−43	+42	+15	−11	+ 9	+7.5	−2.0	−11.5	−0.6	+2.6	−0.9	+1.2	+1.5	+0.7	−0.8	0.0	−1.0	−0.8	+1.8	−0.5
8	−56	0	+33	−22	−40	+26	− 8	− 4	+ 3	+7.0	+0.2	−10.5	−0.4	+3.1	−0.9	+1.4	+2.2	+0.7	−0.1	+0.5	−1.1	−1.1	+1.6	−0.5
9	−46	−12	+24	−40	−33	+11	−22	+ 3	− 4	+5.9	+2.2	−6.7	−0.2	+3.7	−0.7	+1.2	+2.7	+0.7	+0.7	+0.9	−1.2	−1.3	+1.2	−0.4
10	−35	−25	+18	−50	−23	− 6	−37	+ 9	−13	+4.7	+4.0	0.0	+0.7	+3.8	−0.3	+1.0	+2.5	+0.8	+1.5	+1.2	−1.3	−1.4	+0.7	−0.2
11	−23	−35	+12	−23	−11	−22	−49	+14	−12	+3.3	+5.2	+2.0	+4.1	+3.2	+1.1	+0.7	+1.5	+1.0	+2.2	+1.4	−1.3	−1.5	+0.1	+0.2
12	−12	−43	+ 7	−21	+ 3	−36	−59	+15	−31	+1.9	+5.4	+3.3	+4.7	+2.3	+1.6	+0.4	+0.6	+1.2	+2.8	+1.6	−0.6	−1.5	−0.6	+0.9

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TABLE III.

Diurnal Variation of the Smoothed Values of the Horizontal Component of Magnetic Force Directed Along the Meridians and Parallels of Disturbance for Eight Selected Stations.

[Unity = 0.00001 C. G. S.]

Mean Goettingen Time	Kingua Fjord		Jan Mayen		Sodankylä		Greenwich		Tiflis		Zi-ka-wei		Batavia		Cape Hoorn	
	x'_s	y'_s	x'_s	y'_s	x'_s	y'_s	x'_s	y'_s	x'_s	y'_s	x'_s	y'_s	x'_s	y'_s	x'_s	y'_s
1a	+ 5	−49	−31	− 3	−52	−10	−0.8	+4.8	+4.1	+2.5	0.0	0.0	+3.2	+0.9	−1.4	−1.2
2	+12	−43	−46	+ 3	−44	− 9	−0.5	+4.8	+3.9	+1.5	−0.5	−0.5	+3.4	0.0	−1.4	−1.9
3	+16	−33	−53	+ 2	−33	− 9	−0.1	+5.3	+3.6	+0.3	−0.9	−0.7	+3.3	−1.1	−1.2	−2.4
4	+20	−24	−83	+ 3	−21	− 7	−0.7	+5.5	+3.2	−1.3	−1.2	−0.9	+2.9	−1.5	+0.8	−3.1
5	+22	−17	−68	+15	−11	− 5	−2.3	+4.7	+2.7	−3.2	−1.3	−1.0	+2.3	−1.1	+0.1	−3.5
6	+24	−13	−52	+19	− 2	− 2	−3.3	+2.3	+2.0	−3.5	−1.3	−1.1	+1.4	−0.7	+0.7	−3.7
7	+26	− 8	−37	+19	0	0	−4.9	+0.1	+1.0	−1.4	−1.2	−1.2	+0.3	−0.2	+1.3	−3.7
8	+26	− 4	−23	+19	0	+ 2	−4.5	−1.6	+0.2	−0.1	−1.1	−1.1	−1.2	+0.3	+1.7	−3.3
9	+25	+ 2	−12	+18	+ 2	+ 7	−4.3	−2.4	−1.8	+0.7	−1.0	−0.9	−2.2	+0.7	+2.0	−2.5
10	+22	+10	+ 1	+17	+ 5	+ 8	−4.3	−2.9	−3.7	+1.0	−0.9	−0.7	−2.6	+0.9	+2.2	−1.2
11	+21	+18	+24	+26	+13	+ 9	−4.1	−2.8	−4.3	+1.0	−0.8	−0.5	−2.9	+1.0	+1.9	+0.6
Noon	+15	+27	+35	+26	+21	+ 9	−3.8	−1.9	−4.3	+0.2	−0.7	−0.4	−3.0	+0.8	+1.4	+2.4
1p	+12	+35	+50	+28	+32	+ 8	−3.4	−0.9	−4.0	−1.3	−0.5	−0.3	−3.1	+0.2	+0.8	+4.0
2	+ 7	+44	+62	+25	+41	+ 8	−2.2	−1.5	−3.3	−2.2	−0.4	−0.4	−3.1	−0.4	+0.2	+4.6
3	+ 1	+54	+73	+20	+52	+ 8	0.0	−3.7	−2.0	−1.4	−0.2	−0.4	−3.0	−0.7	−0.1	+4.1
4	− 5	+61	+78	+ 9	+61	+11	+2.1	−4.0	−1.5	−0.2	0.0	−0.1	−2.4	−1.0	−0.3	+3.3
5	−15	+59	+72	0	+52	+ 6	+4.1	−3.7	−1.3	+0.9	+0.2	+0.3	−2.0	−0.9	−0.5	+2.5
6	−35	+33	+50	−16	+38	+ 1	+7.2	−1.7	−1.2	+1.7	+0.8	+0.8	−1.4	−0.5	−0.6	+2.1
7	−58	+ 6	+25	−35	+19	− 4	+7.8	+0.6	−1.1	+2.4	+1.4	+1.4	−0.8	0.0	−0.8	+1.8
8	−55	−11	+ 6	−45	− 5	− 7	+6.5	+2.5	−1.0	+2.9	+1.6	+2.1	−0.1	+0.5	−1.1	+1.6
9	−47	−21	−12	−50	−21	− 6	+4.8	+4.1	−0.9	+3.6	+1.5	+2.6	+0.7	+0.9	−1.3	+1.2
10	−39	−32	−26	−47	−38	− 8	+3.1	+5.4	−0.1	+3.8	+1.3	+2.4	+1.5	+1.2	−1.4	+0.7
11	−30	−39	−11	−23	−51	− 8	+1.4	+6.0	+3.4	+5.9	+0.9	+1.4	+2.2	+1.4	−1.5	+0.1
12	−20	−44	−19	−11	−60	−11	0.0	+5.7	+4.1	+3.3	+0.5	+0.6	+2.8	+1.6	−1.5	−0.6

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Station	Disturbance Latitude	Disturbance Longitude
Kingua Fjord	78° N	64° W
Jan Mayen	71 N	21 E
Sodankylä	62 N	43 E
Greenwich	52 N	6 E
Tiflis	35 N	46 E
Zi-ka-wei	20 N	124 E
Batavia	18 S	101 E
Cape Hoorn	45 S	78 W

The components x'_s and y'_s, computed for this new system of co-ordinates from the smoothed values of x_s and y_s, are tabulated in Table III. The deviation of the new north, the north of disturbance, from the geographical north amounts at

Kingua Fjord	9° W	Tiflis	11½ W
Jan Mayen	35 W	Zi-ka-wei	6 E
Sodankylä	24 W	Batavia	1 E
Greenwich	18 W	Cape Hoorn	2 W

The vector diagrams reproduced in the first plate are constructed by means of these components x'_s and y'_s.

For reference the geographical N, E, S, and W directions have been added.

In the map (second plate, left hand side) the value of the vertical component z_s as well as the horizontal vector (x'_s, y'_s) at 12^h m. t. of Greenwich = $12^h 40^m$ m.t. of Göttingen has been inscribed at the place of each station and from that point the successive hourly values along the parallel of the station at distances of 15° from W to E. Further the lines of equal vertical intensity have been drawn and thus the field of force has been constructed.

The arrows indicate merely the direction of the horizontal vector, their length not representing the magnitude which varies too greatly for the Arctic and tropical stations to make this practical.

In the case of the vector nearly vanishing, the arrow has been replaced by a small circle, the direction being very doubtful in this instance.

The map makes it evident, that the lines of equal vertical intensity inclose various foci, of which two may be said to be double. The eastern Arctic one, which shows two maxima over 50 γ (γ=0.00001 *C. G. S.*) owes this feature perhaps to the fact that for these regions the field depends on the values of two stations, Kingua Fjord and Jan Mayen, differing much in longitude. It

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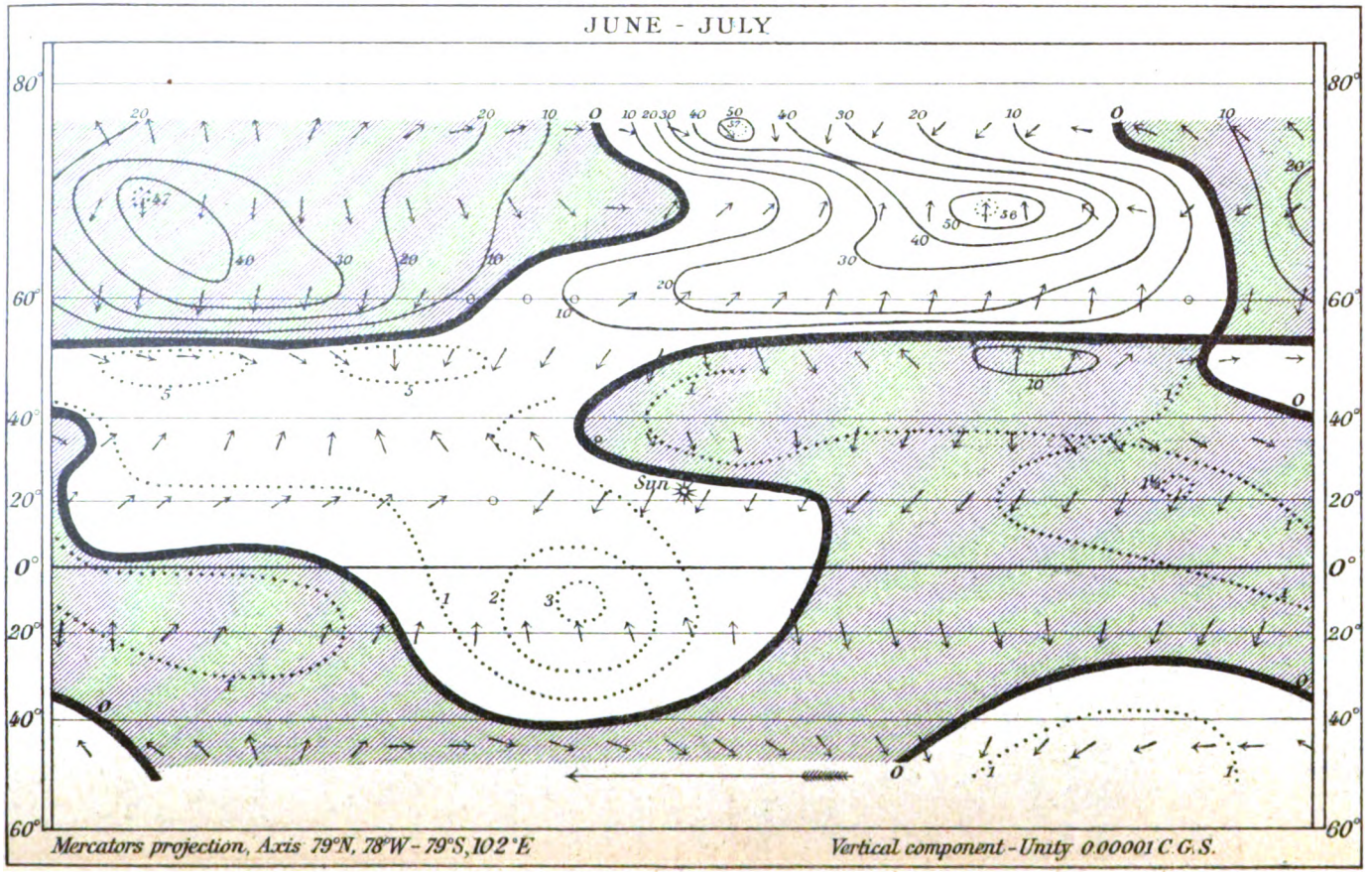
Daily Field of Disturbing Force.

Horizontal Vectors and Lines of equal Vertical Component.



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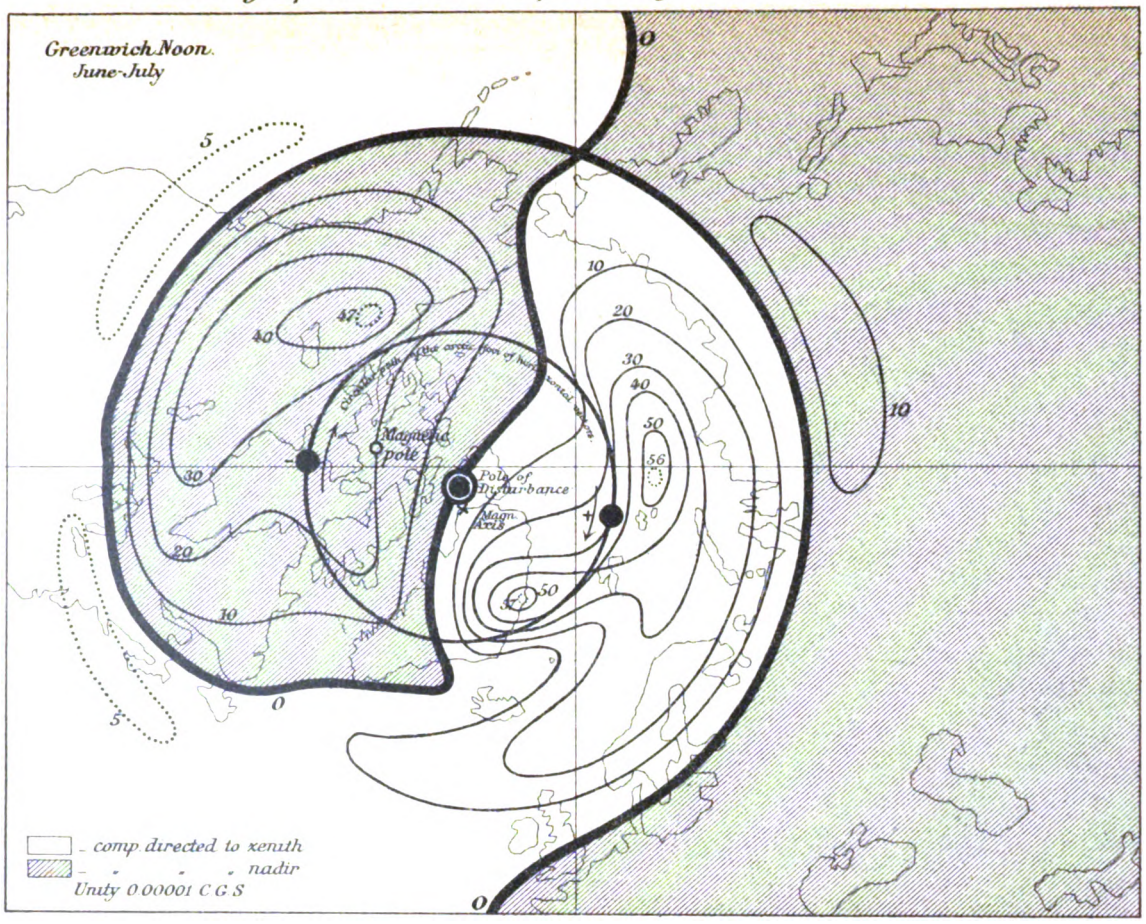
Lines of equal Vertical Component of Disturbing Force



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seems not improbable that only a single focus exists, which, however, suffers some change during the daily rotation.

The two western foci on the parallel of Greenwich owe their existence to the values of this station only; notwithstanding it seems better to consider both as the two centers of a double focus.

From the foci in southern latitudes the eastern one is partly shown on the map, but the western one is only indicated; the existence, however, of two Antarctic foci, corresponding to the Arctic ones, may safely be accepted.

Considering the directions of the arrows it is obvious, that they point with great regularity towards the positive foci and radiate from the negative ones.

As the Arctic foci can better be represented on a map in stereographic projection, such a map has been constructed and reproduced in the plate (right-hand side). The two foci of the horizontal vectors of the Arctic stations and their circular path, discussed above, have been introduced as well as the pole of disturbance, the north end of the magnetic axis of the Earth and the magnetic pole, in order to make it apparent, how much nearer the pole of disturbance is situated to the former than to the latter.

The positive and the negative focus of horizontal vectors are situated close to the region where the vertical component shows a maximum and a minimum, respectively; the positive one lies between the two maxima, the negative following the minimum.

On the Cause of the Diurnal Field of Disturbance.

The current view of geophysicists on the fields of force causing the diurnal variation and disturbance is, that they are generated by electric currents flowing above and below the Earth's surface.

If we suppose a current ring to exist outside the Earth in a plane parallel to its surface, then the lines of equal vertical magnetic force on the surface will be concentric with the projection of that ring. In case the ring moves in its own plane, the course of the lines of equal vertical force in regard to the moving projection of the ring will deviate from their original course, in consequence of currents induced in the Earth's crust, in proportion to the rate of motion and the conductivity of the crust.

In case the path of the primary current is not a ring and we are dealing with a system of currents inclosing various centra, the lines of flow will be less and less concentric with those of equal vertical force, the more intricate the system.

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According to the results obtained in this paper we may suppose as a first approximation, that the daily field of disturbing force is generated by the existence of a system of current rings inclosing eight foci. As the horizontal vectors point to the foci of maximum component, directed to the zenith, this system of currents, according to Ampère's rule, must be situated chiefly outside the Earth.

When a current ring moves centrally over a place, the influence of current induced in the Earth is such, that the extreme value of the vertical component for that place occurs after the moment the center passes, the horizontal component vanishing before this moment. From the representation of the field for the Arctic cap, we may conclude, that the negative focus and the minimum ($-47\ \gamma$) of vertical component are related in a contrary way, the latter preceding the former. For the positive region of vertical component the double focus makes any result ambiguous. In how far this may be understood as an objection to the hypothesis of electric currents is quite uncertain.

Schuster remarks that the course of the equipotential lines of his field of diurnal variation will deviate only slightly from the lines of electric flow, which may be supposed to be the cause of the production of the field. Hence we are allowed to compare directly the lines of equal vertical force drawn here for the field of disturbance, with the equipotential lines of the field of diurnal variation as it has been constructed by von Bezold[1] based on Schuster's calculations.

The most striking difference may be said to be, that the areas of positive and negative potential of diurnal variation are approximately bisected by the meridians of noon and midnight whereas the areas of upward and downward disturbing force are approximately bisected by the line of separation of day and night.

Finally it is to be remarked, that the foci of the Northern Hemisphere are strongest in the summer; a computation for Jan Mayen gives a considerable reduction for winter.

It is indeed desirable to extend the investigation of the diurnal variation field over the polar regions, but in these regions, though the use of quiet days may have great advantage, as shown by Lüdeling in the paper quoted above, the phenomena still remain

[1] *Sitzungsberichte der Akademie zu Berlin*, 1897, p. 271. Tafel III.

See *T. M.*, Vol. IV, p. 48, or Vol. III, p. 111.

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rather intricate. Besides a day selected in the usual way as a quiet one is not to be considered as entirely free from disturbance.

To prove this 26 couples of successive days for the summer months have been chosen out of the days selected by Wild as quiet ones for Petersburg–Pawlowsk. They are:

1873 June 7— 8	1886 Aug. 22—23	1896 July 23—24
" 22—23	1887 June 14—15	1897 Aug. 27—28
1877 June 2— 3	Aug. 11—12	1898 July 17/18—18/19
" 3— 4	1888 July 13—14	1899 June 6/ 7— 7/ 8
1882 July 14—15	Aug. 10—11	July 28—29
1883 June 4— 5	1890 Aug. 30—31	Aug. 11—12
July 21—22	1891 June 12—13	" 15/16—16/17
" 22—23	1893 Aug. 27—28	" 18—19
" 28—29	1895 June 25—26	

The differences of corresponding hourly values of H and D have been taken for each couple and the mean difference for each hour has been calculated. By means of the latter the diagram of the horizontal differential vector has been constructed, which proved to be quite regular and to rotate clockwise, i. e., in the same direction, which is preponderant in the daily diagram of the disturbing vector. This points to the existence of disturbing vectors during such days as are considered to be undisturbed.

These hourly values, mentioned above, expressed in 0.00001 *C. G. S.* are:

Hour	1	2	3	4	5	6	7	8	9	10	11	Noon
HdD	0.1	0.8	-0.4	-1.1	0.3	0.7	0.1	1.3	2.1	2.5	0.8	1.2
dH	-2.0	-1.2	-1.1	-0.5	-1.6	-2.9	-2.1	-1.1	0.9	2.5	0.5	0.9

Hour	1	2	3	4	5	6	7	8	9	10	11	Midnight
HdD	-0.7	-1.2	-1.7	-1.3	-2.4	-5.1	-1.1	-1.4	-0.7	-0.1	2.2	1.0
dH	1.8	1.4	1.6	2.2	0.3	0.2	-0.6	-4.1	0.1	-1.2	-1.4	-0.9

Dr. Fritsche, in his paper on the diurnal variation of the magnetic elements,[1] has extended the computation of the potential function over the polar regions, but I think his results for these parts of the globe are not trustworthy. He makes use of the data for Arctic stations calculated for all days, taking the average diurnal variation for these stations, divided into two groups, viz., Polhem,

[1]Die tägliche Periode der erdmagnetichen Elemente. *St. Petersburg*, 1902.

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Cape Thordsen, Ssagastyr, Karmakul, Point Barrow, and Jan Mayen, Bossekop, Kingua Fjord, Fort Rae. From what has been found in this paper with regard to the disturbing phenomenon, it is evident that the diurnal variation derived in the manner stated is different for Arctic and for non-Arctic stations, the result from the former stations deviating strongly from what is understood to be the true solar-diurnal variation. No doubt the great differences in the elements observed at Arctic stations from those calculated by Fritsche are due to his data having been derived without excluding days of disturbances.

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ATMOSPHERIC ELECTRICITY AND TERRESTRIAL MAGNETISM AT THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE 1903.

By A. Lawrence Rotch.

These topics were more than usually prominent at Southport, on account of the joint meeting of the International Meteorological Committee under the presidency of Professor Mascart, by reason of the interest aroused by Sir Norman Lockyer's paper before the Physical Section of the Association and from the fact that the presidential address to the Geographical Section was delivered by a magnetician.

There were present a majority of the International Meteorological Committee, besides several members of two subcommittees, including the writer. The proceedings, so far as they related to the above subjects, were as follows: The Royal Saxon Academy of Sciences submitted the text of resolutions adopted by the Commission on the Physics of the Globe, regarding the scientific organization of investigations in atmospheric electricity, and it was decided that if these resolutions were approved by the International Association of Academies, the Committee would aid in having the investigations undertaken. Dr. Paulsen, of Copenhagen, exhibited an instrument for collecting atmospheric electricity by radio-active salts. It was voted that Dr. Snellen, who had resigned the directorship of the Royal Dutch Meteorological Institute to take charge of the magnetic observatory at De Bilt, near Utrecht, be authorized to receive and distribute the observations on quiet magnetic days. The question proposed by Rev. J. de Moidrey concerning disturbed days was referred to the magnetic subcommittee. It was announced that Professor Rücker had consented to remain chairman of this committee, which would hold a meeting in conjunction with the British Association at Cambridge in August, 1904.

There was organized a very interesting exhibition of instruments, etc., in connection with the meeting. The Hydrographic Department of the Admiralty showed instruments for observing the magnetic inclination at sea, as used from 1772 until the present time, and also Hansteen's instrument for observing the horizontal force. The Greenwich and Kew Observatories exhibited magnetic records and the last-named institution showed also an early form of Thomson's portable cage-electrometer and an old pattern dip-circle. Captain Creak had on view several charts

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illustrating the changes in magnetic declination since 1700. Professor Pernter, of Vienna, exhibited the Bendorf self-registering electrometer for atmospheric potential, in which the collector is a copper disk covered with radium bromide.

A large number of diagrams of solar changes and of related terrestrial changes illustrated the communication by Sir Norman Lockyer, already referred to, which it was surmised might form the subject of his address as president of the Association, but which was fortunately presented to the Physical Section where it could be discussed. The paper is reprinted in *Science*, November 13, 1903, the conclusions reached by the author being that solar prominences are not only the primary factors in the magnetic and atmospheric changes occurring in our Sun, but that they are also the inciters of the terrestrial variations.

These views were combated by Father Cortie, of Stonyhurst Observatory, who said that recent researches by Father Sidgreaves, Dr. Chree and himself regarding the relation that exists between Sun-spots and terrestrial magnetism had emphasized the general connection of the phenomena, but had disproved any connection of efficient cause and effect. The results of the inquiries were more consistent with the existence of a common cause which affected the Sun and the magnets on the Earth. The question had been raised some time since by Dr. Garibaldi, and more recently by Sir Norman and Dr. Lockyer, as to whether prominences might not supply the place of Sun-spots in those cases in which a great magnetic storm was unaccompanied by any spot, but it would appear that prominences could not, in general, be isolated from Sun-spots, as phenomena which were particularly active in influencing terrestrial magnetism. The question still remained whether particularly large and violent eruptive prominences might not produce magnetic storms in the absence of spots. A detailed study of individual prominences and magnetic storms for the years of minimum spots, 1887–8, had been made, and out of 48 important prominences, 29 were found to be immediately associated with spots or faculæ, or occurred in spot zones. From the declination observations at Stonyhurst it was found that in only one case was a magnetic storm observed when there was a high prominence, and only nine magnetic disturbances occurred during such periods, allowing three days before and after each observation of a prominence. In no single case could a magnetic storm be connected certainly with any particular prominence.

Two papers by Dr. Bauer, of Washington, were abstracted by Professor Schuster. The first paper dealt with the progress of the magnetic survey of the United States, and stated that Maryland has now the most detailed magnetic survey of any country except Holland. Holland has one station to every 40 square miles, Maryland one to every 100 square miles, and England one to every 139 square miles. By 1910–15 it is

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planned that there will be, on the average, in the United States one magnetic station to every 600–900 square miles. Five magnetic observatories are in operation. The second paper concerned the Earth's total magnetic energy, for the space outside of the Earth's surface, and it was calculated that there has been a loss of nearly 3 per cent between the years 1838 and 1884, indicating, if true, that the Earth's magnetism is dying out at an alarming rate. As, however, the data on which the calculations must be based appear insufficient, no definite conclusion was reached. The address of the president of the Geographical Section treated this year of terrestrial magnetism, Captain Creak reviewing the development of our knowledge of the magnetic conditions of the globe. The address is published in full in *Nature*, September 24, 1903.

In a paper on cosmical radio-activity, before the Physical Section, Professor Schuster asked whether radio-activity is not, like magnetism, a common property of all matter, enormously exaggerated in certain substances. The question arose whether the effect would be cumulative and should appear in the cosmic aggregations of matter. Like the Sun and the neighborhood of a radio-active body, the Earth is charged with negative electricity, and this charge must constantly be renewed, as the leakage due to the spraying of ocean waves and the hot gases escaping from chimneys would ultimately dissipate the charge. According to Elster and Geitel 1⅓ per cent of the charge was lost per minute, so that, if the air in the neighborhood of the ground had this conductivity, the Earth would lose its negative charge in an hour. We are living, therefore, in an electric field through which negatively charged particles (cathode rays) are constantly driven outward and which possesses an electric conductivity similar to that found in the neighborhood of radio-active bodies. The similarity of the rays of the solar corona to cathode rays has often been pointed out, and Professor Schuster has long maintained that the assumption of an increased conductivity of space at the time of a Sun-spot maximum would explain the connection between Sun-spots and terrestrial magnetism.

A paper by Messrs. Elster and Geitel, of Wolfenbüttel, Brunswick, on radio-active emanations in the Earth's crust and atmosphere, was presented in abstract by Dr. Lees. The authors have carried on in Wolfenbüttel, since 1899, continuous observations on the dispersion of atmospheric electricity, and periodical observations all over Europe under the most varied conditions. The dispersion of atmospheric electricity, which is high in caves, seems to be connected with the degree of ionization and with the radio-activity of certain emanations from the soil. If the radio-activity on the sea-coast is 1 then it is 4 at Wolfenbüttel and 30 in the Alps.

Dr. W. J. S. Lockyer exhibited photographs of lightning to illustrate the different types observed—ramified, stream, multiple dark-flashes, etc.,

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and of the few spectra of lightning so far obtained. The first-order spectrum is characterized by two bright lines and several fainter ones and also some dark lines, and Dr. Lockyer is inclined to favor the assumption that the lightning-spectrum is simply the air-spectrum, as was asserted by Professor Pickering, who first obtained the spectrum of lightning.

Dr. Paulsen, in a paper on a comparison of the spectrum of nitrogen and the aurora borealis, described the results of the investigation by the Danish Commission in Northern Iceland during 1899–1900. Two spectrographs were used—a French one, consisting of an Iceland-spar prism and quartz lenses, and the other of German construction, with flint lenses and a prism of higher luminous power, which photographed down to the line *O* of the solar spectrum. Twenty-three lines were photographed, under great difficulties, of which sixteen were unknown. Measurements were made on the spot, and, later, by comparison with the cathode glow and spark discharges. Most of the auroral lines agree with the nitrogen lines, but the principal auroral line does not.

Through the courtesy of Professor Schuster a few physicists and meteorologists were shown his laboratory in the Owens College, Manchester.

Blue Hill Meteorological Observatory.

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EARLY HISTORY OF THE MARINER'S COMPASS AND EARLIEST KNOWLEDGE OF THE MAGNETIC DECLINATION ACCORDING TO BERTELLI.

By D. L. Hazard.

I. THE EARLY HISTORY OF THE MARINER'S COMPASS.[1]

As early as 1866 P. Timoteo Bertelli began the study of the origin and early history of the mariner's compass. The results of his investigations were published in detail in 1893 in a paper entitled "Studi storici intorno alla bussola nautica." His conclusions met the approval of most scientific men; but there were some prominent men in Italy who took exception to his views as to the compass being of Chinese origin and who maintained that the compass was invented as well as perfected at Amalfi, Italy. Bertelli's later contributions to the subject, in reply to these opponents, present the results of his more recent investigations, and treat some phases of the subject in greater detail than was the case in the earlier publications. His conclusions are presented under four general heads.

1. A careful examination of the writings of more than seventy Greek and Latin authors covering the period from the sixth century B. C. to the tenth century A. D. failed to find any mention of the directive property of the lodestone, nor any suggestion from which one might conclude that this directive property was used either in navigation, astronomy, or surveying during that long period of time, though there are numerous descriptions of voyages and storms at sea, where mention of the compass would be expected, if it had been in general use at the time. Apparently the only facts about the lodestone which were known at that time were its property of attracting iron and of communicating that attractive power to iron. That the property of polarity was unknown before the tenth century is shown by the fact that Pliny and subsequent writers explained the phenomena of attraction, repulsion, and neutralization of magnetic action by ascribing them to three supposedly different minerals, *magnete*, *teamede*, and *adamas*. Another circumstance supporting the conclusion that the compass was not used in the Mediterranean before the tenth century, is the fact that all the early descriptions of it which we have (by Neckam, Guyot, etc.) speak of it as a new and wonderful thing.

[1] Sulle recenti controversie intorno all'origine della bussola nautica. P. Timoteo Bertelli, Roma, 1902. lg. 8°, 52 pp.

La Leggenda di Flavio Gioia, inventore della bassola. Osservazioni del P. T. Bertelli, Barnabita, Firenze, 1903, 8°, 28 pp.

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2. Leaving out of account everything which appears exaggerated or doubtful, it can not be denied that the directive property of the magnet was known to the Chinese before the beginning of the Christian era. In various Chinese and Japanese writings there are repeated descriptions of the so-called south-pointing carts, of which the distinctive feature was a doll attached to a magnet and mounted on a pivot, so that an outstretched arm was always directed toward the south. For instance, the Japanese history (Nip-pon-ki) gives an account of the first use of one of these carts in Japan in 658 A. D., and relates that in 666 A. D. one was presented to the emperor by a Chinese Buddhist priest. In fact these carts seem to have been reserved for the use of the emperors almost exclusively. There is also mention in Chinese books now generally accepted as authentic, of the early use of a rude compass with floating needle. As China looked upon all other nations as barbarians and therefore had no desire to enter in commercial nor political relations with them, her commerce was confined almost entirely to her own rivers and coast. There was therefore very little need for a compass, and probably very few vessels were provided with them. For that reason, also, there was no incentive for improving upon the original form of compass, and it was still in use by the Chinese even after the first voyages of the Portuguese to China.

3. One of these crude compasses with floating needle, as used in some Chinese vessel, was probably introduced into the Mediterranean by the Amalfians about the tenth century. There appears to be no direct evidence on this point, but as the Amalfians were very enterprising and were permitted by the Arabian Government to traffic with the extreme East, it seems not at all improbable that on some voyage a compass was brought home as a curiosity. They soon improved upon it by substituting a pivoted needle for the floating one, and by adding the graduated "Rose of the Winds" which moved with the needle. From Amalfi the use of the compass spread gradually to other parts of the Mediterranean and to the seas of the North.

The first European writer to mention the primitive compass with floating needle was the English monk Alexander Neckam, toward the end of the twelfth century. Peregrinus first describes the compass with pivoted needle, in his famous Epistola, written in 1269. Benjamin ascribes to him the invention of this improvement of the compass, but Bertelli concludes that the pivoted compass was in use as early as the end of the twelfth century.

4. The names of the various persons who between the tenth and fourteenth centuries introduced and perfected the compass are all unknown, and there is no foundation for the tradition which ascribes to a certain Flavio or Giovanni Gioia the invention and important improvements of the compass about the beginning of the fourteenth century.

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This tradition appears to have originated during the last half of the sixteenth century, since a careful scrutiny of the writers of that and the preceding century who wrote about the compass failed to find any mention of the name of the inventor before that time, most of them stating that his name was unknown. The first writer to refer to the *first* use of the compass in the Mediterranean was the learned Flavio Biondo, who, about 1450, made a first attempt at a history of Italy. Speaking of the compass he says: "Sed fama est qua Amalphitanos audivimus gloriari, magnetis usum, cujus adminiculo navigantes ad arcton diriguntur, Amalphi fuisse inventum, quidquid vero habeat in ea re veritas, certum est id navigandi auxilium priscis omnino fuisse incognitum."

Giovanni Battista Pio, in his "Commentaries on Lucretius" (edition of 1511), makes the following remark in regard to the lodestone: "Amalphi in Campania veteri magnetis usus inventus a Flavio traditur: cuius adminiculo navigantes ad arcton diriguntur: quod auxilium priscis erat incognitum." By comparing this with the passage given above it will be seen that Pio quoted almost word for word from Flavio Biondo and in the clause "a Flavio traditur," he gives Flavio as his authority. Giambattista della Porta, also, in his "Magia Naturale" (First edition, Naples, 1589), uses almost the same words in referring to the origin of the compass, but leaves no doubt as to his meaning when he says, "*ut* a Flavio traditur." Giraldi, however (apparently from a misinterpretation of the passage from Pio, quoted above), gives the credit for the first use of the lodestone as an aid to navigation to an Amalfian named Flavius; for he says: (1580) "Amalphis in Campaniae oppido antiquis navigandi usus incognitus per magnetem et chalybem, quorum indicio nautae ad polos diriguntur, a Flavio quodam excogitatus traditur." Giraldi was the first writer to give the name Flavio to the inventor of the compass, and it is to him that the beginning of this erroneous tradition can be traced. Many writers subsequent to the fifteenth century have either left the question in doubt or have stated positively that the name of the inventor is unknown. Indeed, Lipenio, after mentioning the authors who ascribe the invention to a certain Flavius, says: "Boni isti viri inventoris et scriptoris nomina confundunt; Flavius enim non inventor erat, sed scriptor.

Bertelli shows that Mazzelli, who first (1586) gave Flavio di Gioia as the name of the inventor, and Ortelio, who (1596) used the name Giovanni Gioia, are both untrustworthy historians, at least in what they have to say about the compass. Of later writers, some have used one name and some the other, while some have given credit for the *invention* of the compass to Flavio, and for its *improvement* to Giovanni Gioia. Bertelli concludes, therefore, that there is no foundation in fact for the tradition which ascribes to a particular individual the invention or improvements of the compass.

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II. WAS THE MAGNETIC DECLINATION KNOWN TO THE CHINESE BEFORE THE TIME OF COLUMBUS?[1]

Some writers maintain that the fact that the compass needle does not in general point exactly to the pole of the heavens was known to the Chinese several centuries before its discovery by Columbus. In evidence of this they cite passages, of which the context is nearly the same, from two Chinese books; "Pen-thsao-yan-i," a natural history of the early part of the twelfth century, and "Mung-khi-po-tan," of about the same epoch, discovered and translated by Stanislaus Julien. The passage from the latter reads as follows: "The soothsayers rub a needle with the lodestone; it will then indicate the south. It declines constantly a little to the east, however; it does not indicate the south exactly. When this needle floats on water it is much agitated. If the finger-nails touch the edge of the basin in which it floats it is very much disturbed; it continues to slide, however, and easily falls to the bottom. In order to show its (directive) property to best advantage it should be suspended in the following manner: Take a single thread from a new skein of cotton and fasten one end of it to the exact middle of the needle by means of a bit of wax as small as a mustard seed. Suspend it in a place where there is no wind, and the needle will then continuously indicate the south." The other passage adds "that if the needle be made to float on water by means of a bit of reed, it will also show the south, but always with a declining toward the point 'ping.'" Ping is the first point to the east of south, each point being 15°.

Bertelli takes exception to the conclusion that these passages show a knowledge of the magnetic declination by the Chinese of that early day. He points out that in both passages it is clearly stated that the property of the needle is best shown when the needle is suspended by a fiber, and that then it points to the south, as though the writers considered its failure to point exactly south when floated to be due to the inferior method of suspension. This was the interpretation adopted by Biot, and he therefore concluded that the declination was very nearly zero at that time in China. Bertelli ascribes the "declining" of the needle when floated to the surface tension of the water, which would prevent the needle from turning freely under the influence of the horizontal component of the Earth's magnetic force. This would not account for its always declining to the east of south, however.

If the Chinese had known of the declination as early as the twelfth century, it is reasonable to presume that the knowledge would have

[1] Della declenazione magnetica presso i Cinesi. P. TIMOTEO BERTELLI, Roma, 1903, 8°, 10 pp.

Nuova conferma che la declinazione magnetica era ignota ai Cinesi prima di Cristoforo Colombo. P. TIMOTEO BERTELLI, Pavia, 1903, 8°, 6 pp.

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been handed down from generation to generation. We find, however, that when at the beginning of the seventeenth century the Jesuit mathematician and astronomer, Matteo Ricci, and some of his fellow-missionaries were allowed by the emperor of China to take part in the so-called Tribunal of Mathematicians, it was with great difficulty and only by ocular demonstration that they were able to convince the Chinese scientists that the magnetic and astronomic meridians are not coincident. At that time the declination at Peking was about 2° west, as determined by Ricci. Nearly two centuries later Amiot found that the Chinese still assumed the declination as 2° west in placing their sun-dials, showing that the knowledge of the fact was preserved for two centuries after its demonstration by Ricci.

Bertelli concludes, therefore, that Columbus and not the Chinese, was the discoverer of the magnetic declination.

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LETTER TO EDITOR

REQUEST FOR LIST OF MAGNETICALLY CALM DAYS.

Le 9 Septembre 1903 le Comité réuni à Southport, a résolu:

1. Que M. Snellen sera chargé de recevoir et de distribuer les observations sur les jours calmes, et
2. Que la question des jours troubles (proposée par Rév. J. de Moidrey) sera remisa à la Commission magnétique.

Par conséquent, vous êtes prié à envoyer dès à présent les observations sur les jours calmes directement à *Monsieur M. Snellen,*
Chef du Service magnétique à De Bilt près Utrecht, Holland

H. HILDEBRAND HILDEBRANDSSON,
Upsal, le 30, Septembre, 1903. Le Secrétaire,
Comité International Météorologique.

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THE MAGNETIC ELEMENTS OF FORTY-FOUR STATIONS IN MADAGASCAR, DETERMINED BY PROF. P. COLIN, DIRECTOR OF THE TANANARIVE OBSERVATORY.

J. W. FROLEY.

The magnetic elements of the first thirty-six stations given in the table were communicated by Prof. Colin to the *Comptes Rendus* for June, 1902. On application to him for information as to the positions of the stations, he sent me a French Army chart with these thirty-six stations and eight additional ones plotted thereon. The co-ordinates of the positions were expressed in grades which have been reduced to degrees and the origin of longitudes has been transferred from Paris to Greenwich. The longitudes of all the stations are made to depend on that of Tananarive Observatory as given by French Hydrographic charts.

In a discussion of the observations Prof. Colin notes that there are striking anomalies at several places which he terms centers of perturbations. First, at Tsiafajavona, the highest peak of the chain of the Ankaratra, the needle, instead of pointing N. N. W., points N 3° 15′.8 E; the inclination, which should be about 54° 30′, falls to 47° 45′.2. The Ankaratra by virtue of its mass and altitude, exercises considerable influence on the surroundings. At distances removed considerably from the eastern side of the plateau toward Andraraty, Amhatolampy, Antsiriribé and Morarano, the three elements return to their ordinary values.

A second center of perturbation, less distinct than that of the Ankaratra, is in the neighborhood of Vontovorona. The anomaly begins with a minimum of the three elements at Antanifotsy, south of Morarano; then the declination and inclination increase until Soandrarina is reached; at the latter place the intensity drops 0.004 *c. g. s.* below the normal. The reverse takes place on the summit of Vontovorona, viz: decrease in declination and inclination and increase in intensity.

On the other side of Vontovorona extends a volcanic zone. The difference in declination between the two stations at Antsirabé, 300 meters apart equals 9′. Between Antisirabé and Betafo, the difference in declination is a half degree, and the intensity decreases by 0.004 as at Soavinandriana.

North of Betafo at Tokotanitsara there appears a remarkable discordance in the declination which is N. 38° 18′.5 W. The needle is deflected by the solid mass of basalt of the Vavavato, which is 2 km. to the Westward. At the three stations near this chain, Antanifotsy, Manaribefona, and Belamosina, the three elements increase gradually.

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On the edge of the crater lake of Vinaninony, at Tsarazafy, anomalies in the horizontal component exhibited themselves.

The irregularity in the intensity and in the declination is shown still more on the summit of Ambohipoloalina.

At Dango, the declination decreases, the intensity increases; a comparison of Faratsio and Raimainandro shows values nearly regular, slightly increased, however, by the proximity of the Ankaratra a disturbance extends to these stations. At Andakandrano the needle resumes its normal direction. At Ampefy on the edge of the crater lake the declination is a minimum for that region, and it is a maximum on the ancient volcano of Ambasy. The value of the horizontal component becomes less in this last place, and greater at Soavinandriana. The inclination is a little large at Ampefy and at Soavinandriana.

The disturbing influence discontinues where the volcanic zone terminates. At Ambohimiangara and Miarinarivo, the distribution of the magnetic forces appears uniform. A slight decrease in declination is indicated at Arivonimamo, due probably to the attractive influence of the neighboring mountain Ambohimpanompo.

In conclusion Prof. Colin observes, that in the central uplift in Madagascar, the magnetic perturbations extend furthest and affect most the ridge of the Ankaratra to Vontovorona as well as the ramifications of the uplift of the Vavatao, that the eastern plateau which borders the foot of this ridge has a magnetic field of greater regularity than the western plateau; that the volcanic zones have a local influence of small extent.

U. S. HYDROGRAPHIC OFFICE, WASHINGTON, D. C.

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	Place	Latitude S.	Longitude E of Gr	Date 1901	Declination	Dip South	Hor'l Int.	Description of Station	Character of the Surface Soil.
		° ′ ″	° ′ ″	Sept.	° ′ ″	° ′ ″	γ		
1	Andramasina	19 11.0	47 56.8	10	9 25.7 W.	. . .	. . .	Outside of village, close to cemetery.	Red clay mixed with humus.
2	Aᴴmahavony	19 18.8	47 39.9	11	14 48.3 "	. . .	. . .	On plateau, near a monument.	Red clay.
3	Antanamalazakely	19 24.7	47 41.7	11–12	10 22.3 "	54 42.9	. . .	Near rock, in middle of plateau.	Clay mixed with humus; granite.
4	Tsinjoarivo	19 38.2	47 44.8	12	10 39.0"	54 40.5	25152	Center of court, old mansion.	Reddish colored clay.
5	Sarobaratiakely	19 36.2	47 36.8	13	10 51.3 "	. . .	. . .	Near monument, emblem, idolatry.	Auriferous, quartzy earth, containing iron.
6	Antsiriribé	19 36.0	47 31.8	14	11 04.3 "	. . .	25069	North of village, at end of walk.	Red clay.
7	Ambatolampy	19 22.6	47 28.0	15	10 49.7 "	54 45.1	25161	On plaza, near executive offices.	Clay, large granite rocks to westward.
8	Andraraty	19 21.9	47 22.0	17	10 28.4 "	54 34.0	25062	Near ditch, S. W., of village.	Red clay.
9	Tsiafajavona	19 21.0	47 16.8	18	3 15.8 E.	47 45.2	. . .	Peak, near geodetic station.	Volcanic rocks (Néphélinite basaltique); influential on the magnet.
10	Morarano	19 32.2	47 21.9	19	11 06.0 W.	54 54.8	25066	Close to Catholic Church.	Red clay.
11	Antanifotsy (East)	19 39.5	47 22.4	20	10 36.7 "	54 50.4	24944	On plateau, near Church.	Red clay.
12	Betampona	19 48.0	47 19.3	21	10 48.8 "	55 18.2	24724	On plateau, N. W. of village.	Red clay; to northward, rocks of a cellular texture.
13	Soandrarina	19 54.2	47 16.7	22	12 49.6 "	56 22.8	24339	Near monument, west of village.	Grayish colored clay.
14	Vontovorona	19 54.4	47 15.4	23	10 32.2 "	50 14.5	24633	Peak, near geodetic Station.	Ancient volcano of conical form. (Trachyte phonolitique), slightly magnetic.
15	Aᴴdranandriana	19 53.2	47 12.8	23	12 09.9 "	. . .	. . .	North of the village.	Alluvium soil; marl, quartz.
16	Antsirabé	19 52.9	47 05.0	24	11 14.6 "	55 38.5	24732	Center of garden of Catholic Mission.	Yellow clay; soil of volcanic origin.
16a	" (Hot Spring)	. . . .	. . . .	25	11 23.6 "	. . .	. . .	By cistern, north of hot spring.	Trachytes, basalt, calcareous concretions; peat.
17	Betafo	19 50.3	46 55.0	25–26	11 44.3 "	55 47.7	24318	On plaza, 200 meters north of Catholic Mission.	Volcanic earth; volcanic ashes.
18	Iavoko	19 51.2	46 57.1	26	12 03.9 "	. . .	. . .	On summit of little hill.	Ancient volcano notched; on east side strong flow of lava. (Scories basaltiques).
19	Antanifotsy (West)	19 41.4	47 00.9	28	10 41.4 "	55 00.6	24812	500 meters east of village.	Rose colored clay; volcanic rocks to the west (basalt much changed, a little magnetic).
20	Manarilefona	19 39.0	47 01.6	28	10 52.6 "	. . .	24890	100 meters west of village.	Yellow clay; large rocks to the eastward.
21	Tokotanitsara	19 38.7	46 58.9	29	38 18.6 "	. . .	. . .	2 meters east of edge of plateau.	Volcanic rock; scorie basaltique, magnetic.
22	Belamosina	19 35.4	46 58.3	29–30	11 48.5 "	55 23.2	25202	100 meters south of village.	Red clay; burnt rock in the neighborhood.
23	Tsarazafy	19 33.2	46 59.2	30	12 21.2 "	53 11.6	24845	60 meters N. E. of village, on spur of hill.	Crater lake of the ancient volcano, trachyte augitique; magnetic, quartz; yellow clay,
				Oct.					
24	Faratsio	19 23.3	46 59.8	1	11 04.6 "	54 51.3	25033	In field south of Catholic Church.	Gray colored clay, quartz.
25	Aᴴpoloalina	19 23.1	46 57.1	2	15 35.7 "	. . .	19337	Near geodetic signal.	Black soil; trachyte phonolitiqne; magnetic; burnt rocks; quartz; lignite to the northwest.
26	Andakandrano	19 17.8	46 52.9	3	10 46.8 "	. . .	. . .	150 meters N. W. of village.	Red clay, very micaceous; quartz.
27	Dango	19 17.3	46 55.0	3	14 54.4 "	. . .	24512	Peak, east of masonry work, close to rock.	Large hill with four lakes.
28	Ramainandro	19 17.9	47 03.4	3	11 05.2 "	54 31.1	24984	Above village, below Governor's garden.	Light colored soil; granite; quartz; in the valley hot springs; volcanic.
29	Soavinandriana	19 09.6	46 47.9	4–5	10 40.3 "	55 32.8	24655	In middle of plaza, north of village.	Volcanic ashes, basalte limburgitique, magnetic; 6 kilometers southwest of ancient volcano; 12 kilometers to hot springs; frequent trembling of the earth.
30	Ambasy	19 05.9	46 47.4	5	11 43.2 "	. . .	24388	On summit, close to pile of rocks.	Ancient volcano of conical form; scorie basaltique, magnetic.
31	Ampefy	19 02.8	46 47.3	5–6	9 25.6 "	54 57.9	. . .	Near the gate, north of village.	Alluvium soil, on the edge of the crater, Lake Itasy.
32	Aᴴmiangara	18 59.9	46 55.0	6	10 32.2 "	. . .	25358	Near geodetic signal.	Soil covered with fragments of quartz. Primitive mica much altered. non-magnetic.
33	Miarinarivo	18 57.2	46 57.4	6–7	10 30.6 "	53 51.6	25236	Garden of Catholic Mission.	Reddish clay.
34	Sohamanina	18 59.4	47 03.2	7	. . . .	58 55.8	. . .	On high road, S. E. of village.	Red clay; 1 kilometer south and east, abundant iron ore.
35	Arivonimamo	19 00.5	47 13.6	7–8	9 56.3 "	53 45.8	25604		
36	Tananarive (Observ.)	18 54.8	47 36.2	16–19	10 19.9 "	53 56.3	25779	In field, 100 meters north of Catholic Normal School.	Red clay; 1.5 km. to the east, large granite rocks; in the vicinity of volcanic rocks.
				1902 April				New magnetic pillar.	Red clay; hunk of gneiss.
37	Aᴴmpanompo	18 59.9	47 16.5	12	13 51.5 "	. . .	24383	Near geodetic signal.	Granite rocks.
34	Sohamanina	18 59.4	47 03.2	13	6 18.0 E.	54 54.2	25069	Near gate, S. W. of village.	Iron ore.
38	Amboanana	19 07.9	47 13.8	14	10 39.0 W.	53 59.7	24846	Plaza, north of village.	Red clay.
39	Aᴴfohitrimo	19 05.9	47 05.4	15	10 21.0 "	54 20.6	25005	On road, 200 meters south of village.	Red clay.
				Sept.					
40	Behenjy	19 12.7	47 32.6	22	. . . .	54 42.6	. . .	Near the commissary headquarters.	Red clay.
41	Ambatolampy	19 22.6	47 28.0	23–54	10 36.1 "	54 53.1	24827	10 meters west of position for 1901.	Clay, granite rock to the west.
42	Miantsoarivo	19 11.9	47 27.6	25	9 48.1 "	54 17.0	25434	60 meters N. W. of Catholic Mission.	Red clay.
43	Fehibé	19 08.5	47 23.0	26	11 01.6 "	55 42.1	24599	Plaza, center of village.	Burnt rocks; vicinity of flint cinders; reddish yellow clay.
44	Tsizangaina	19 05.6	47 27.3	26–27	10 37.7 "	54 16.6	25358	North Gate, Catholic Mission.	Red clay; granite mountain northwest.

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NOTES

16. *The Great Magnetic Disturbance of October 31, 1903.* A number of interesting reports have been received from various sources, the publication of which will be deferred until the next issue when a brief summary can be attempted of what has become known thus far with reference to this disturbance, as also a tabulation given of the notable disturbances and of allied phenomena during 1903.

Since October 31st, notable disturbances occurred December 13th–14th, and December 29th–31st.

17. *Corrigendum.* *M. Moureaux* informs the Editor that the set of field instruments used by him in his magnetic survey of France was not designed by him, as might be inferred by the appellation, "Moureaux-Chasselon," used on pp. 63 and 64 of the June issue of the Journal in referring to the large corrections due to the impurity of the brass found in a set of these instruments purchased by the Coast and Geodetic Survey. The dip circle was designed by *M. d'Abbadie* and the magnetometer by *M. Mascart* and the first sets were constructed by *M. M. Brunner.*

18. *Magnetic Survey of South Africa.* *Professor J. C. Beattie* writes that "the magnetic survey of South Africa is going on fairly well. Observations have already been made at over three hundred stations between Cape Town and the Zambesi, and it is hoped to observe at about one hundred and fifty more stations."

"*Father Goetz* at Bulawayo has agreed to do what he can in Rhodesia.

"We hope very much to get permanent stations at Bulawayo, Bloemfontein, Cape Town, and perhaps also in the Transvaal and in Natal."

In the interest of magnetic science in the Southern Hemisphere, we must congratulate Professor Beattie upon what he has already accomplished and trust that his efforts to secure the erection of some magnetic observatories will also be crowned with success.

19. *The Bahama expedition of the Baltimore Geographical Society* under the leadership of *Professor G. B. Shattuck*, of the Johns Hopkins University, secured some valuable magnetic data, in the Bahamas during June and July of this year. The observations were made by *Dr. O. L. Fassig*, section director of the U. S. Weather Bureau at Baltimore with a set of instruments loaned by the Coast and Geodetic Survey, in which Bureau the observations are being reduced; the results will be communicated later.

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20. *Observatoire de l'Ebre.* From a manuscript report by *Father R. Cirera, S. J.*, kindly put at the disposal of the Editor by *Father Hagen*, in charge of the Observatory of the Georgetown University, the following facts are extracted: Plans have been formulated for the erection of an observatory equipped with magnetic, astronomical, meteorological and atmospheric electricity instruments for the general investigation of problems in cosmical physics. It will be situated near Tortose, in the eastern part of Spain, near the mouth of the river Ebre; the geographical coordinates are approximately 40° 48′ latitude and longitude 1° 47′ west of Paris, or 0° 33′ E. of Greenwich. The principal instruments are under construction and it is hoped that the work can be begun at the end of 1904. The magnetic instruments will be a Mascart magnetograph and eye-reading set, Kew magnetometer for the absolute observations and an earth-inductor.

The site appears to be a well-chosen one, free from any disturbing influences of whatever kind. It is in the vicinity of the Jesuit College and will be in the shadow belt of the total solar eclipse of 1905.

21. *Magnetic Observatory at De Bilt, near Utrecht.* We regret to be informed of the loss, by fire, of the variation observatory and that, owing to projected electric car lines, the immediate restoration of the observatory can not be undertaken.

22. *Van Bemmelen's publications.* Dr. W. van Bemmelen has deposited with the bookseller, Martinus Nyhoff, The Hague, Holland, a limited number of copies of the following two publications: "Die Abweichung der Magnetnadel, 1899," "Die säculare Verlegung der Magnetische Axe der Erde, 1900." These copies are for sale. Scientific persons and libraries, however, can procure copies gratis by corresponding directly with Dr. van Bemmelen, Magnetic Observatory, Batavia, Java.

23. *Magnetic Observatory in the Samoan Islands.* In accordance with the information courteously supplied by Professor Wiechert, it is proposed to carry on the work of this observatory, established under the auspices of the Academy of Sciences, Göttingen, until April, 1904. The variation observations were begun early in 1903, the magnetograph being of the Eschenhagen design. The Observatory is situated at Apia.

24. *Magnetic Observatories in the Argentine Republic.* Two magnetic observatories will soon be in full operation in the Argentine Republic, one in the vicinity of Cordova and the other on the island, "Año Nuevo." (See frontispiece.) Fuller details will be given in a future issue.

25. *Peculiar changes in the secular variation in the United States.* Recent observations by the United States Coast and Geodetic Survey have revealed some curious and unexpected secular changes in the magnetic elements occurring in certain parts of the United States. For example, in Maryland it would appear as though the dip diminished at the rate of about 1½′ from 1896 to about 1900, and then increased about

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the same amount so that the dip measured in 1903 exhibits hardly any change over that obtained in 1896 by L. A. Bauer when conducting the magnetic survey of Maryland.

In the South-Middle States, e. g., Kentucky, Mississippi, Louisiana, Texas, Missouri, Kansas, where east declination should be *decreasing at the average rate of about 3′ per annum*, the recent reoccupation of stations previously observed at by the Coast and Geodetic Survey, shows in some regions an *increase* instead of a decrease, and in other regions a diminished rate of decrease.

In other parts of the United States the "repeat" observations give annual changes agreeing, in general, well with the lines of equal annual change laid down on the isogonic chart of the United States for 1902.

It is rather curious to note that the anomalous changes are going on mainly in the region where the departures of the magnetic elements from the values which they would have on the basis of a uniform magnetization of the United States are most pronounced (See T. M., Vol. V, pp. 1–4). In this region, furthermore, there have been of late certain seismic disturbances which have not always been recorded on *seismographs* but have been recorded on the *magnetograph* at the Cheltenham Magnetic Observatory.

It is therefore evident that we have here local causes acting which affect the normal course of the secular variation. [Some instances of the disturbing action of local causes in the secular variation were cited by Captain Creak in his vice-presidential address before the Section of Geography at the recent meeting of the British Association.]

26. *Continuance of Special Rapid Registration Observations.* The five Coast and Geodetic Survey magnetic observatories will continue during 1904 the special rapid registration observations at the following times:[1]

Greenwich mean civil time.	h.	h.	Greenwich mean civil time.	h.	h.
January 1, . . .	21½	23½	April 1, . . .	3½	5½
" 15–16, . . .	22½	0½	" 15, . . .	4½	6½
Jan. 31–Feb. 1, . . .	23½	1½	May 1, . . .	5½	7½
February 15, ...	0½	2½	" 15, . . .	6½	8½
March 1, ...	1½	3½	June 1, . . .	7½	9½
" 15, ...	2½	4½	" 15, . . .	8½	10½

etc., through the entire year.

[1]See T. M., VIII, p. 74.

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ABSTRACTS AND REVIEWS.

SCHUSTER, A. ON SOME DEFINITE INTEGRALS AND A NEW METHOD OF REDUCING A FUNCTION OF SPHERICAL CO-ORDINATES TO A SERIES OF SPHERICAL HARMONICS[1].

This investigation deals with some definite integrals useful in expressing a function of two angular variables by means of a series of spherical surface harmonics. An important theorem is deduced, rendering it possible to determine the Gaussian coefficients of the various harmonic terms in the expression of the Earth's magnetic potential, independently of one another. In the methods hitherto employed, the values of the coefficients of the higher harmonics have depended upon the number of terms used. The author reserves for a future paper, the comparison of the values of the coefficients as obtained by his method, with those of previous computers.

Although we must be thankful to the author for his interesting and valuable contribution to the methods of analyzing the magnetic condition of the Earth, it is questionable whether, at the present stage of our knowledge of the distribution of the Earth's magnetism, any great, *absolute* gain will result. The fundamental step to be taken is, the amassing of homogeneous data fairly uniformly distributed over the zone from about 60° N. to 60° S. L. A. B.

[1] *Phil. Trans. R. S.* Ser. A, Vol. 200, pp. 181–223.

LYONS'S TREATISE ON ELECTRO-MAGNETIC PHENOMENA.[1]

This volume, the second and last of the treatise, fulfills in part the hopes that were aroused by Volume I. The author's experience, and his informal, often clever, style, find here opportunity to unite in producing a semi-popular work on the compass as used in navigation, interesting alike to the mariner, and the layman. To those looking for scientific accuracy, however, the book is likely to prove interesting in a way not intended by the author. It offers an even more varied collection of mis-statements than its predecessor, and the lover of scientific curios would do well to turn its leaves.

It is unfortunate that a book containing the possibilities of such real merit should be so fatally marred, and still more unfortunate that it will doubtless be received by many, both here and abroad, as an example of contemporary American scientific writing. Most of the criticisms made in the review of Volume I, hold equally well here. There are the same disregard of order, omission of definitions, and avoidance of scientific terms in common usage. It is quite consistent with this policy for the author, well on toward the end of Volume II, to state that "plus multiplied by plus produces plus," and to give the rule for squaring numbers, etc. The index is poor, and decidedly incomplete; the cuts are good, except in a few signal instances.

As to the scope of the work, it gives a fairly good idea of the compass as

[1] *A Treatise on Electro-Magnetic Phenomena, and on the Compass and its Deviations Aboard Ship, Mathematical, Theoretical, and Practical.* By COMMANDER T. A. LYONS, U. S. Navy. Vol. II.
The Compass and its Deviations. New York: John Wiley & Sons. 8 vo. pp. 557–1138. (The first volume was reviewed in this JOURNAL for October, 1901, p. 145.)

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used in the U. S. Navy, though not a single good diagram or picture is shown of compass and compensating magnets in actual use. Is the same form of compass used by foreign nations? And on merchant vessels? Why does Kelvin's name receive such scant mention? These are among the questions that remain unanswered. No reason is apparent for not bringing the information down to date. Thus, on page 675, the magnetic elements at Washington are given for 1890; other similar instances might be quoted. Ether *waves*, properly speaking, are everywhere confused in a curious manner with magnetic fluctuations: on page 1114, "Chapter VII, intimately concerns the navigator; it relates to the great magnet—the Earth—to the surgings of its enveloping ether, as Variation, Dip, and Intensity."

Most readers will be surprised to learn that the Dip is "the maximum angle the direction of the dipping needle will make with the horizontal plane;" also that in magnetic calculations, l is the exact length of the magnet, from end to end. A few minor slips have been allowed to remain in the text, such as on page 985, where *dm* should be read for *mm*.

Part Third, "The Ship a Magnet," deserves much praise in spite of its defects. The experiments on the model vessel *Scoresby* are very interesting: the vessel was loaded with masses of iron, and pointed in different directions, and corresponding compass deviation curves are given, first with compass uncompensated, then under the influence of a compensating magnet. It is to be regretted that no curve is shown with the resultant effect of *all* compensating magnets when used at once. The introduction to the subject of sextantal deviations, etc., leaves much to be desired, but the example given, that of the U. S. S. *Ranger*, is excellent, showing a good agreement between theory and observation. The section on compensation of the deviations is also quite well given. A more careful discrimination might have been made between different methods, and a better description of apparatus in actual use, with drawings and dimensions, would have added to the value of the section.

The climax of the whole work is reached in the last part, "Various Matters Bearing on the Main Subject," which in many ways is a source of astonishment even to one familiar with all the preceeding pages. One paragraph is headed "Scales: Earth's Curvature: Duration of Light Flashes:" and these topics are disposed of in eight lines. A curious collection of references is appended in which no mention of the editions referred to is made. We note among other things, the omission of Nipher's "Magnetic Measurements." As an example of the author's inconsistency, the rather inadequate paragraph on the determination of H, is tacked on at the very end of the book.

We are tempted, in conclusion, to quote one or two statements that cast more light on the scientific value of the work, than many pages of criticism:

Page 677. "The azimuth circle.—A few words will suffice for this inseparable adjunct of the compass: every officer who uses it, knows the principles of its construction. It is made by Messrs. Ritchie; the material is brass, painted black, and it is inspected by the superintendent of compasses." Five lines concerning adjustments follow.

Page 842. "Rubbing the glass cover of the bowl with a silk or woolen cloth will excite electric currents in the glass which deflect the needle."

A. L. M.

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AN INTRODUCTION TO PHYSICAL GEOGRAPHY.[1]

G. K. GILBERT AND A. P. BRIGHAM.

This book is designed for the use of pupils beginning the average American high-school course, and the reviewer has not met with any other text or reader which is so well adapted to the needs of that class of pupils. The accuracy of the statements is sufficiently vouched for by the positions held by the co-authors, both of whom have also repeatedly proved themselves excellent teachers.

The language and style have been most happily chosen. The sentences are short, simply constructed, and present clear-cut ideas. Constant, but natural reference to the relation of organic life and human history, to the physical features of the Earth, serves to heighten the reader's interest in the subject. Technical terms are not allowed to occur very often, and when they are used they are defined immediately.

The method of presenting the subject is that known as the "type method," each subject being introduced by the consideration of a type case; the discussion is then extended to include many excellently chosen examples under each type. The authors have not restricted themselves to any one land when looking for a type case, nevertheless, they seem to have found most of their types well represented in North America. Naturally, most of the examples are taken from American localities, since the text is designed for American schools.

The order of treatment and apportionment of space, is as follows:

The Earth and the Earth and Sun, 28 pages; The Lands, 195 pages; The Atmosphere, Weather, etc., 51 pages; The Earth's Magnetism, 5 pages; The Oceans, 23 pages; Shorelines, etc., 17 pages; Life, and the Earth, and Man, 52 pages. This distribution of attention seems quite proper for a book of this grade. The shortest chapter is the one on the Earth's Magnetism, but so clear is the language, that the fundamental truths about the compass, its declination, variation, and dip, are interestingly and sufficiently explained. A map of Isogonics for the United States in 1902, and one of the Magnetic Meridians for North America in 1885 accompany the section.

The use of 3-color contour maps in the text, well-chosen weather maps to illustrate a typical storm, the high character of the pictorial illustrations, and frequent cross-references, are features of special value in this book.

Washington, D. C., January 29, 1904. CLEVELAND ABBE, JR.

New York, D. Appleton & Co., 1904 (publ. 1902.) Size 7.5 inches x 5.25 inches, pp. xvi + 380.

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LIST OF RECENT PUBLICATIONS
WITH BRIEF ABSTRACTS

BIGELOW, F. H. Eclipse Meteorology and Applied Problems. U. S. Weather Bureau. W. B., No. 267. Bulletin No. 1. Washington, 1902; 4°, 166 pp. [Chapters 1, 2, and 3, give an account of the observations by the U. S. Weather Bureau, made during the total eclipse of the Sun, May 28, 1900, at Newberry, South Carolina. Chapters 4 and 5 are concerned with the relations between solar and terrestrial meteorology.]

CREAK, E. W. Terrestrial Magnetism in its Relation to Geography. Address as Vice-President of Section E (Geography), British Assoc. Adv. Science. *Nature*, September 24, 1903. [A valuable and timely summary of the salient facts of the distribution of the Earth's magnetism and its secular variation, the conclusions drawn being very largely based on the author's extensive experience. The principal topics are: "Magnetic Surveys," "The Antarctic Expeditions," "The Magnetic Poles of the Earth," "The Secular Change," "Local Magnetic Disturbance," "Magnetic Shoals," "Terrestrial Magnetism and Geology," "Magnetic Charts and Portable Magnetic Instruments." In conclusion an appeal is made for observations in the regions where they are especially needed, e. g. at sea. The address has been reprinted in the London *Geographic Magazine* and in the *Scientific American Supp.* November 7, 1903.]

FINN, W. Influences of the Sun-spots upon Electrical and Magnetic Forces of the Earth. *Scientific American*, December 5, 1903, p. 2335. [Relates the chief results of his investigations of earth currents in telegraph lines.]

GÜNTHER, S. Das Polarlicht im Altertum. Repr. Gerland's Beitraege zur Geophysik, Bd VI, Heft. 1. Leipzig, 1903. 8° pp. 98–107. [The author concludes that the earliest reports of polar lights date from the Fourth Century B. C., believing that Aristotle's "Chasma" and Pytheas's "Meerlunge" can only be interpreted as referring to polar light phenomena. Other early references appear too doubtful. Reliable references are obtained again from Tacitus and Plutarch. The first thoroughly reliable observation in modern times is that by Konrad Gessner in 1561, as related in his "Historia," Zürich, 1561.]

HAMMER, W. J. Radium and other Radio-active Substances; Polonium, Actinium and Thorium, with a consideration of Phosphorescent and Fluorescent substances, the Properties and Applications of Selenium and the treatment of Disease by the Ultra-Violet Light. New York: D. van Nostrand Co. 1903. 8° 72. pp., 38 illustrations. Price $1. [A lecture delivered at a meeting of the Am. Inst. of Elect. Eng'rs and the Am. Electrochem. Soc., New York, April 17, 1903; the author has endeavored to exemplify by numerous experiments and illustrations the fundamental principles and phenomena of the subjects treated.]

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NIPPOLDT, A. Erdmagnetismus, Erdstrom und Polarlicht. Leipzig. G. J. Göschen'sche Verlagshandlung, 1903. 12°, 136 pp., 3 pl. Price 80 Pf. [This excellent résumé of the fundamental facts and results of the latest investigations in terrestrial magnetism and its allied subjects forms No. 175 of the interesting *Sammlung Göschen*, each number of which is sold, bound in cloth, at the uniform price of 20 cents. While special stress is laid upon German contributions, the author exhibits a wide familiarity with and mastery of the contributions of other nations. Any one who has attempted to correlate, in an international spirit, the recent results of magnetic investigations will appreciate the difficulties of the author's task. For in a summary of this kind one can not content himself with published abstracts but must consult and master the originals, and that implies a familiarity with various languages and sciences.]

PALAZZO, L. Three reprints from "Protokoll über die dritte Versammlung der internationalen Kommission für wissenschaftliche Luftschiffahrt (Berlin 20–25 Mai, 1902.) Strassburg, Dumont-Schauberg, 1903.
Beilage 5. Die Theilnahme Italiens an der internationalen wissenschaftlichen Erforschung der hohen Atmosphäre. 2 pp.
Beilage 6. Die Einrichtung des neuen Observatoriums für die Physik der Atmosphäre auf dem Monte Rosa. 3 pp.
Beilage 19. Ueber ein registrirendes Elektrometer, welches auch für die Ballonfahrten oder Drachenaufstiege benutzt werden kann. 4 pp. [The author has adapted Exner's electroscope to photographic registration of potential differences and suggests modifications so that the photographic instrument could be used in balloon ascents, or with kites.]

ROOSENBURG, L. Der Platz für den Regelkompass. "De Zee," Aug. 1903, p. 339. [Translated from the Dutch into the German, by Dr. H. v. Hasenkamp, and published in Ann. d. Hydr. u. Maritimen Meterologie, 1903, Heft XII, Deutsche Seewarte, Hamburg. Pp. 555–560. Gives a brief statement of the fundamental principles to be observed in the placing of the standard compass on board ship.]

SCHMIDT, ADOLF. Aufgaben und Einrichtung eines erdmagnetischen Recheninstituts. Versammlung Deutscher Naturforscher und Aerzte, Hamburg, 1901. Repr. 8°, pp. 191–194. [Abstract of an address on the problems and organization of a magnetic computing institute, which, while intended primarily for Germany, would also embrace in its scope problems of world-wide interest.]

SCHUSTER, A. Introductory Address as Chairman of Subsection, Cosmical Physics, Brit. Assoc. Adv. Science, 1902. Repr. 12°, 20 pp. [A discussion of the question: "If two events happen simultaneously, or one follows the other after a short interval of time, does this give any reason for supposing that the two events are connected with each other, both being due to the same cause, or one being the cause of the other?" As instances, are taken the investigation of the connection between Moon and earthquakes, and the connection between Sun-spots and rainfall. In conclusion the author dwells upon the necessity of reducing observations, and not merely piling them up or observing aimlessly.]

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STARK, JOHANNES. Die Dissoziierung und Umwandlung Chemischer Atome. 8°, 58 pp. Braunschweig, Vieweg & Sohn. Price unb. 1.50 M. [A timely and excellent résumé of the results of the most recent investigations. Chapter 1 treats of electrical dissociation and conductivity in gases, electrolytes and metals; Chapter 2 is on the cause and nature of radioactivity according to the investigations of Rutherford and Soddy; Chapter 3 is a brief statement of the investigations by Rutherford and Soddy and Ramsay, on the evolution of helium from radium. In conclusion are given numerous notes and references. The author is privatdocent at the University of Göttingen.]

WAGNER, HERMANN. Peter Apian's Bestimmung der magnetischen Missweisung v. J. 1532 und die Nürnberger Kompass-macher. Nachr. d. K. Gesellsch. Wiss. Göttingen. Phil.-hist. Klasse, 1901. Heft. 2. 8°, 12 pp. [In Hellmann's article, "The Beginnings of Magnetic Observations," T. M., IV, p. 80, is given a tabulation of the values of the magnetic declination in the first half of the Sixteenth Century. Wagner shows that Apianus must be credited with a careful determination of the magnetic declination. Wagner's tabulation of the early values is as follows:

Year.	Place.	Magnetic Declination.	Observer or Authority.
1510±	Rome.	6° E.	Georg Hartmann.
1518±	Bay of Guinea.	(11¼ E.)	Piero di Giovanni d'Antonio di Dino.
1520±	Vienna.	4 E.	Joh. Georg Tannstetter (Rheticus).
1523 (?)	Landshut (?) (Bavaria).	9 E.	Petrus Apianus.
1532	Ingolstadt.	10½ E.	Petrus Apianus.
1534	Dieppe.	10 E.	François or Crignon.
1538	Nuremburg.	10¼ E.	Georg Hartmann.
1538	Lisbon.	7½ E.	Pedro Nunes or João de Castro.
1539±	Danzig.	13 E.	Georg Joachim Rheticus.
1541	Paris.	7 E.	Hieronymus Bellarmatus.
1544±	Nuremburg.	10 E.	Georg Hartmann.
1546±	Island Walcheren.	9 E.	Gerhard Mercator.

In the "United States Magnetic Declination Tables for 1902" is given a complete tabulation of all the magnetic declinations made on land prior to 1600, as far as they have become known.

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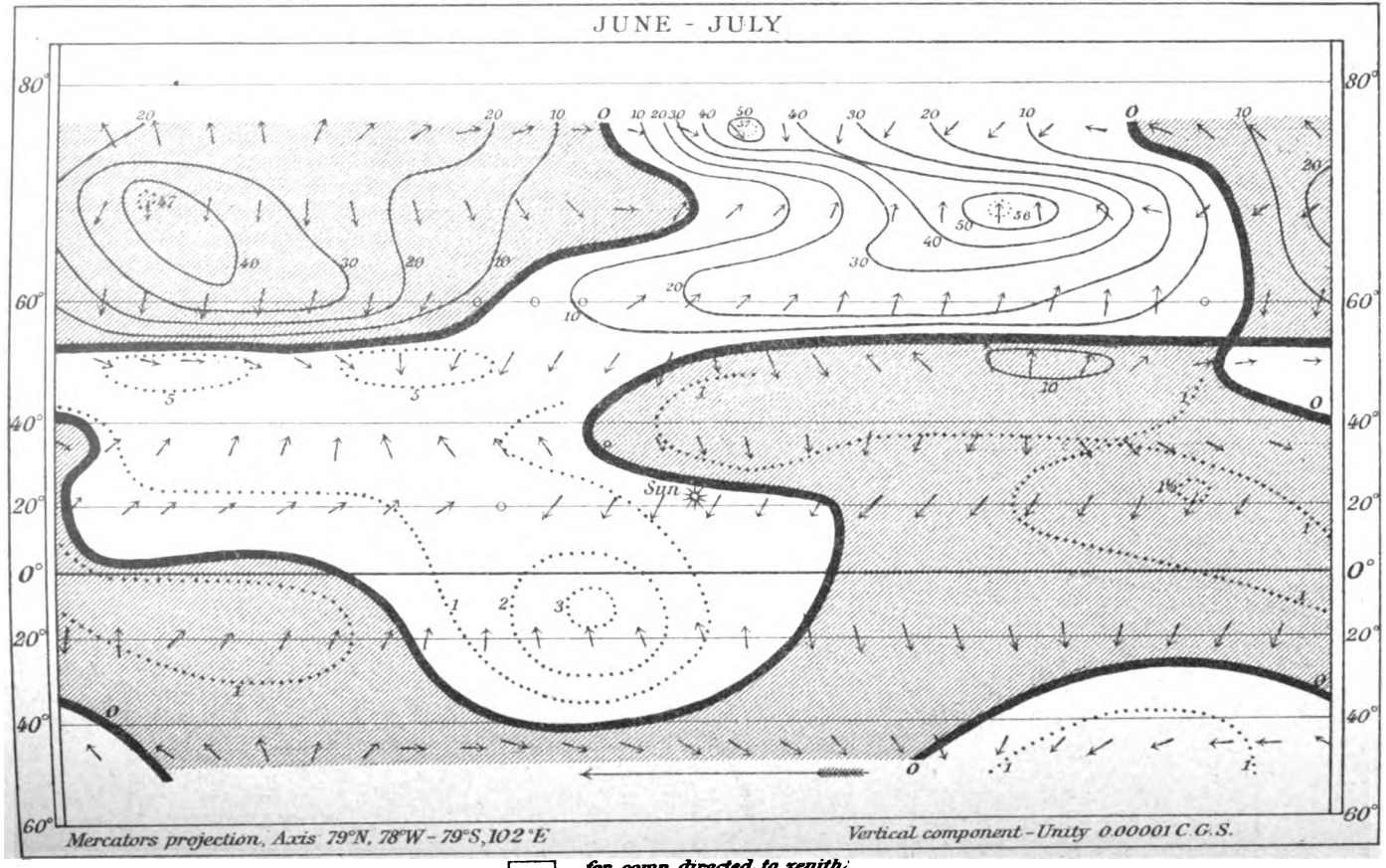
Daily Field of Disturbing Force.

Horizontal Vectors and Lines of equal Vertical Component.



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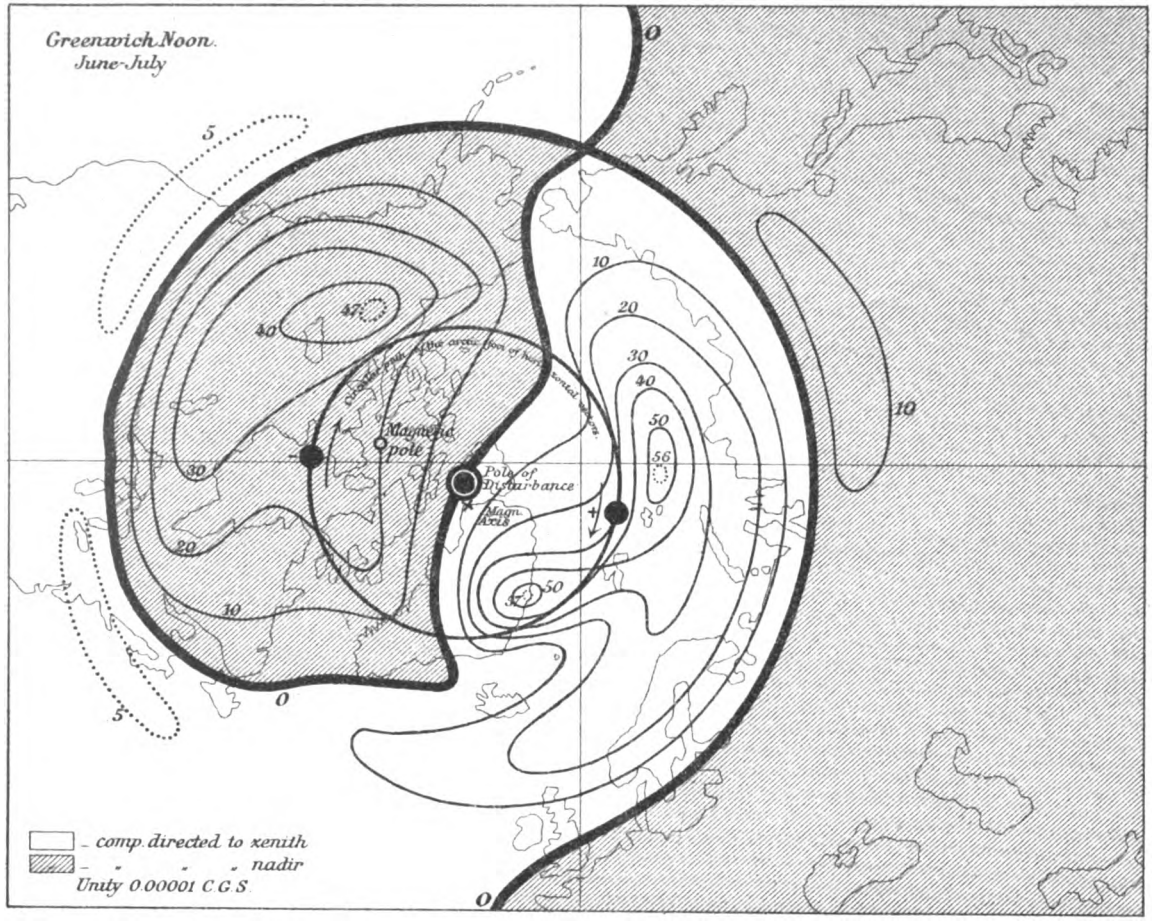
Lines of equal Vertical Component of Disturbing Force.



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